No. Mexico

Name San Lorenzo

Order Thin paper

Remarks Grids 1969

Retouched

Order Finished

Reorder

Reorder

Grid Nos.

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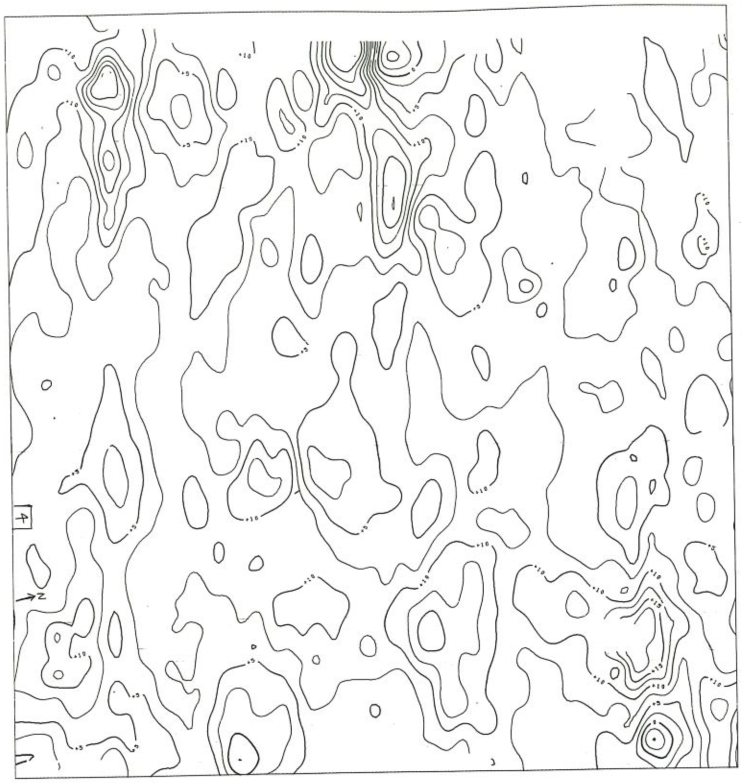

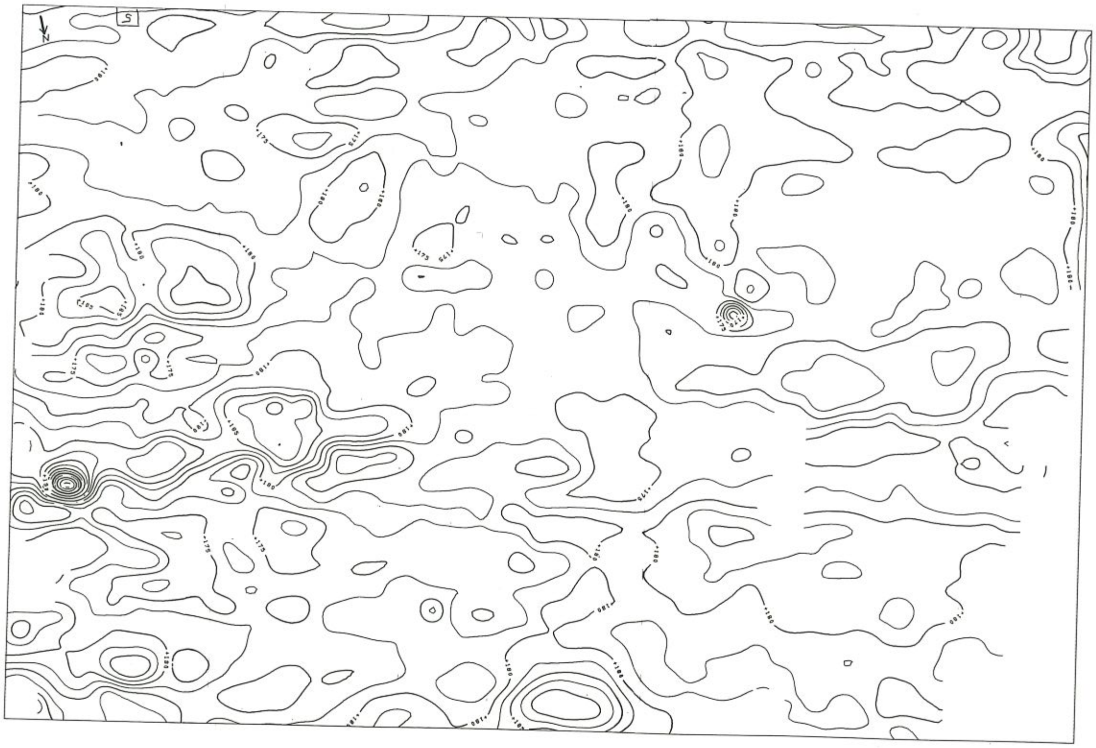

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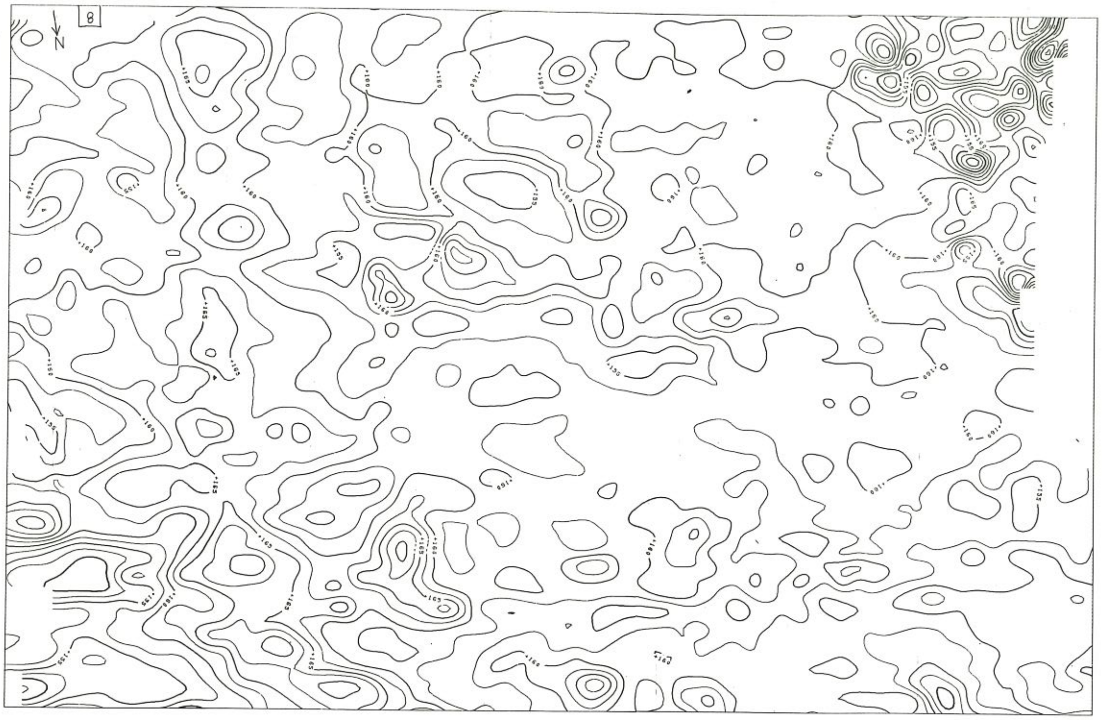

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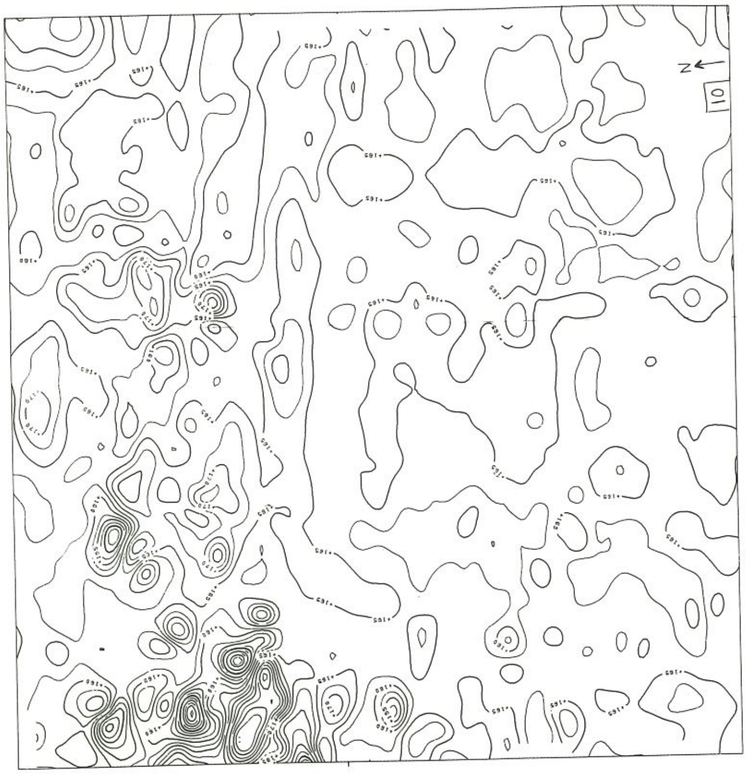
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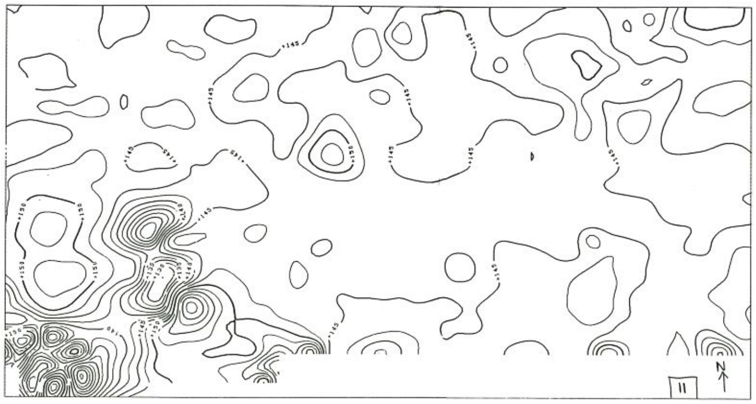
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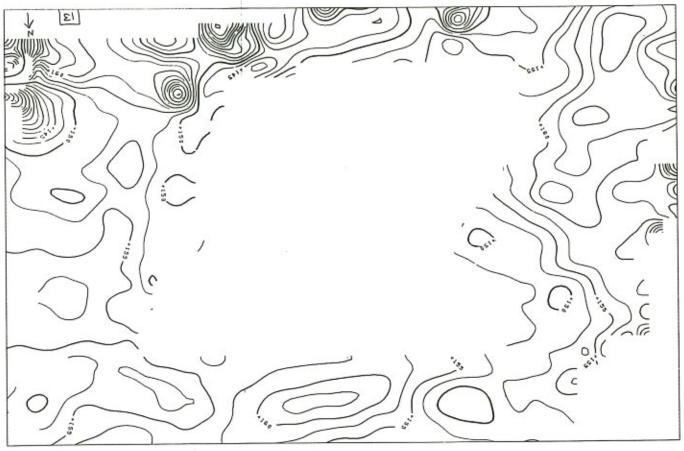

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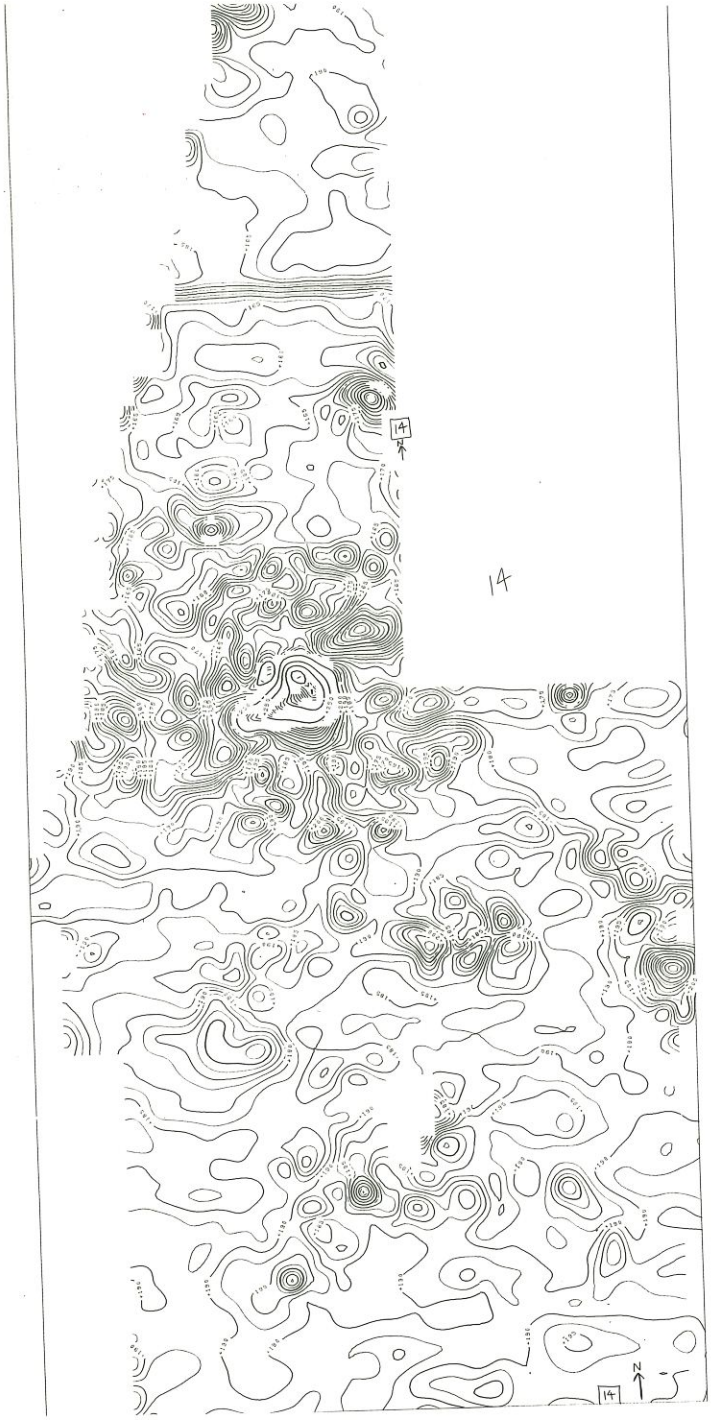
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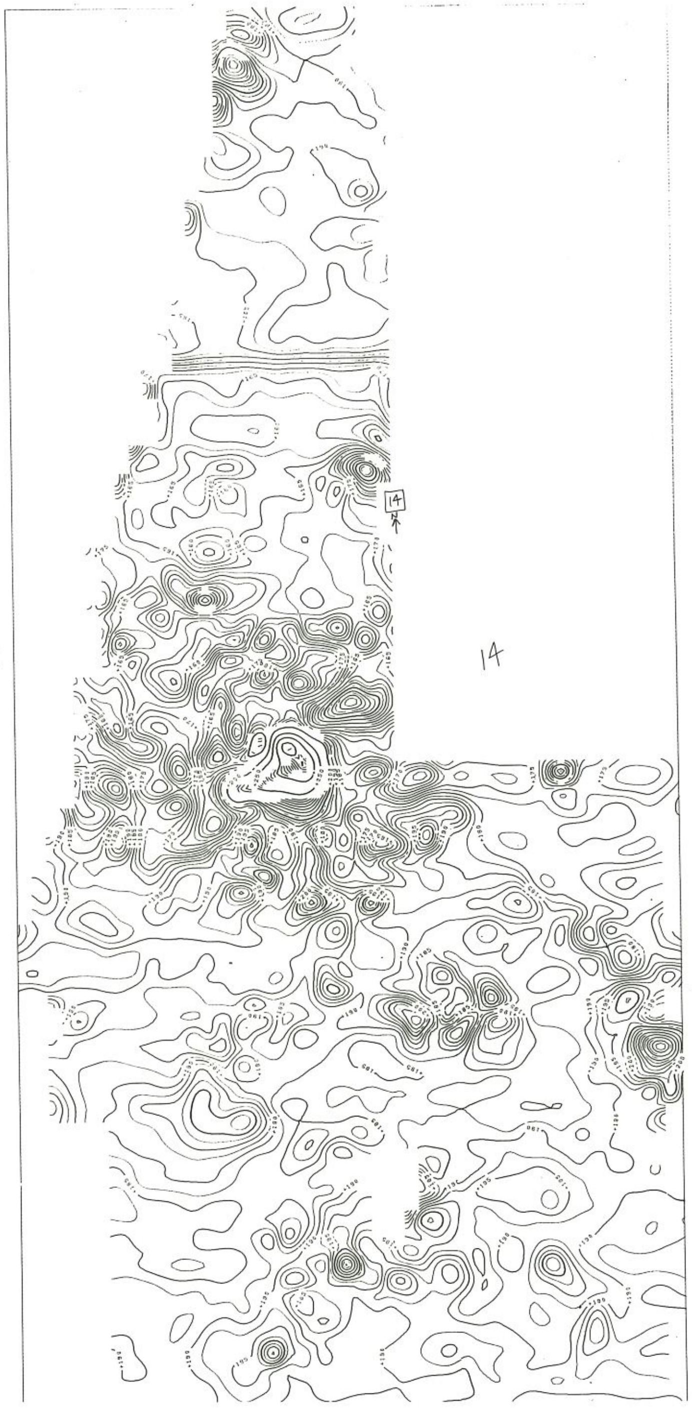
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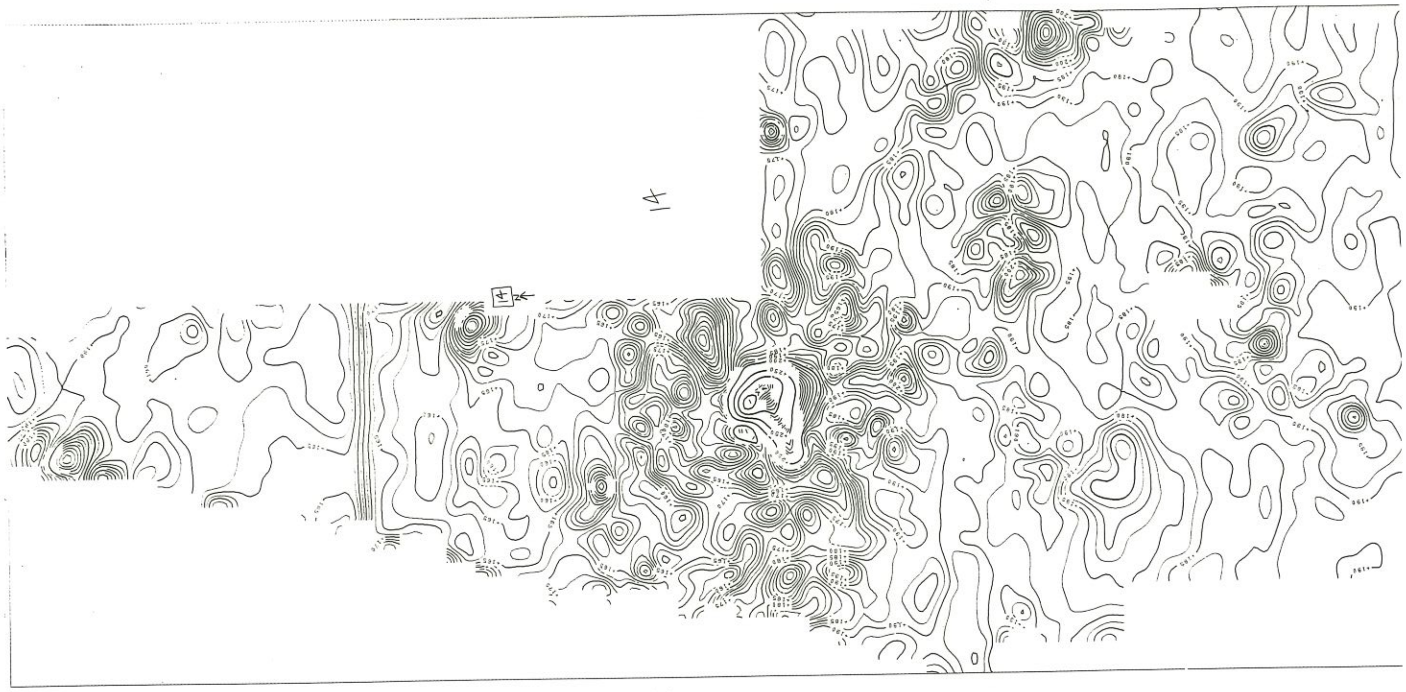

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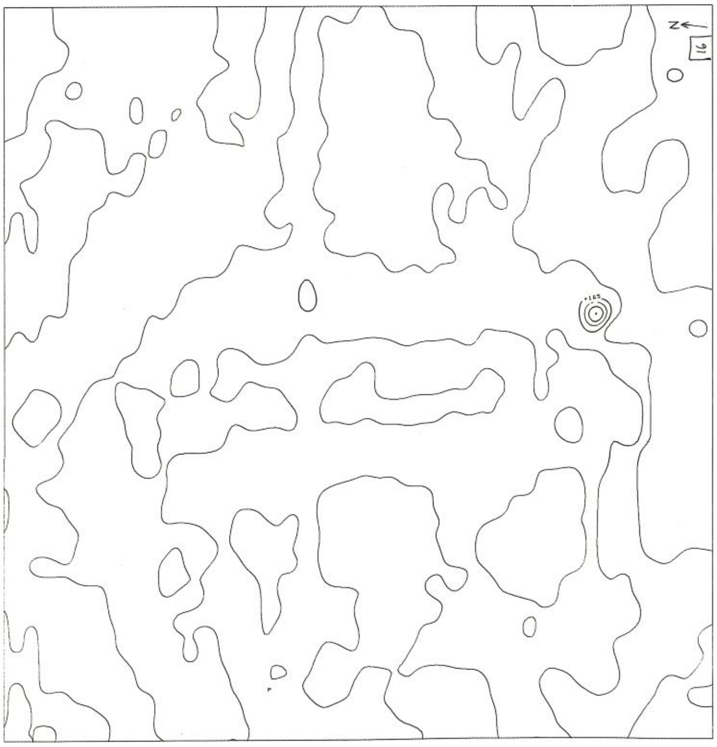

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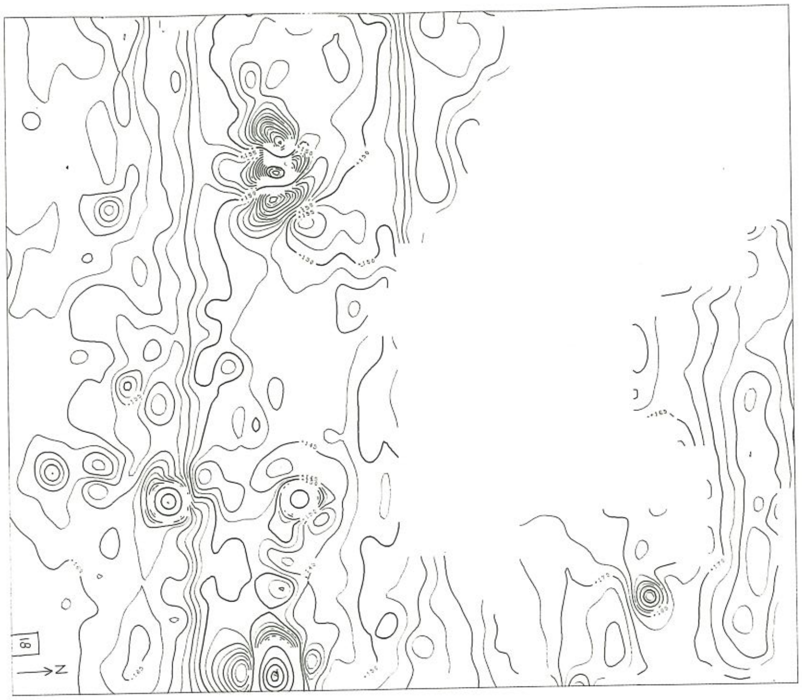

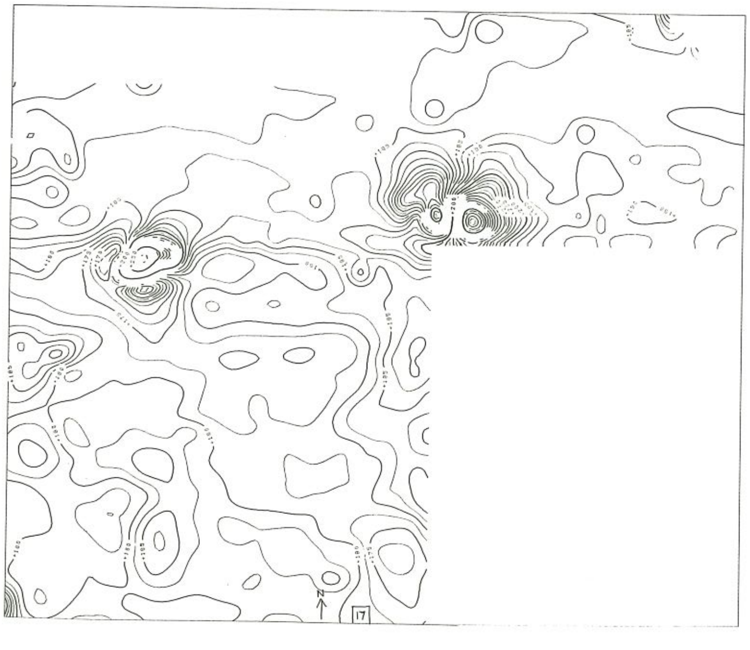

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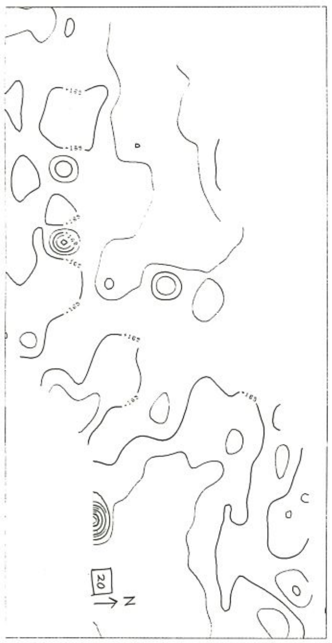

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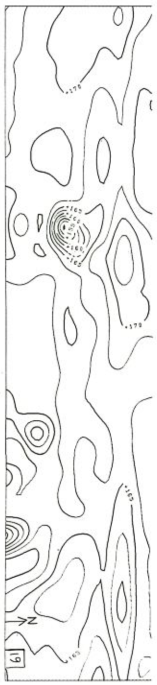

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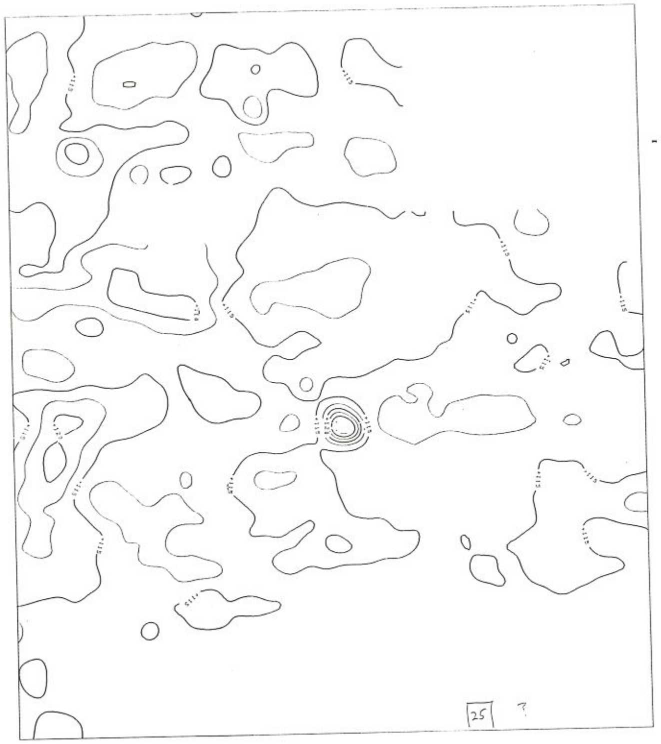

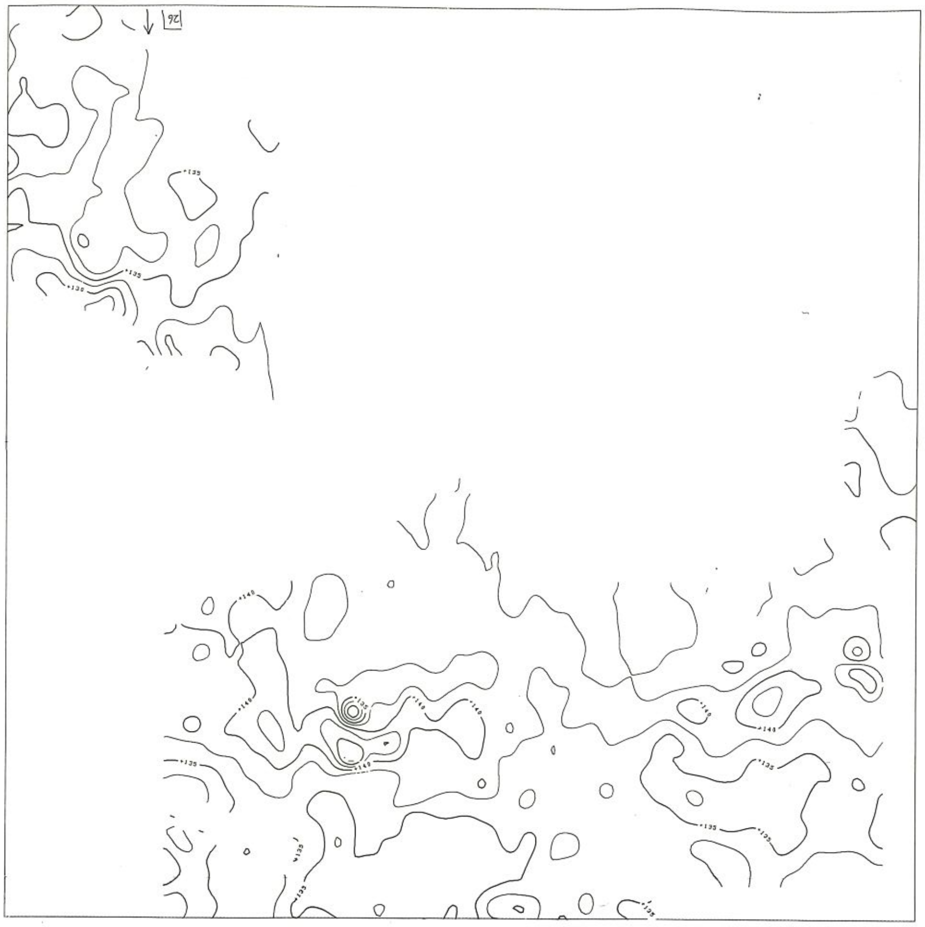
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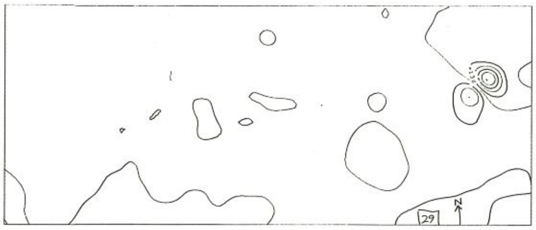
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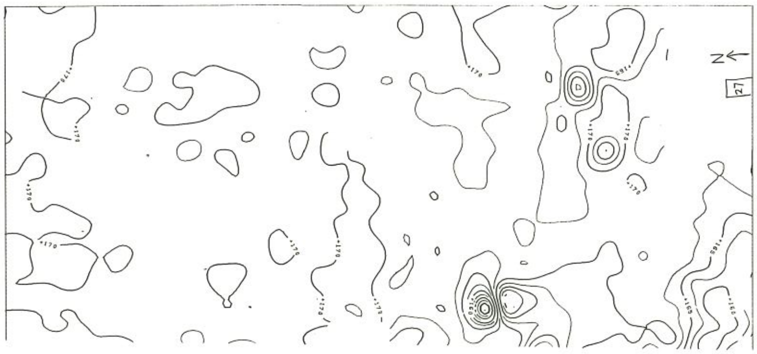
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No. Grid No. 15 Thin paper

Name San Lorenzo

Order Mexico

Remarks 1969

Retouched

Order Finished

Reorder

Reorder

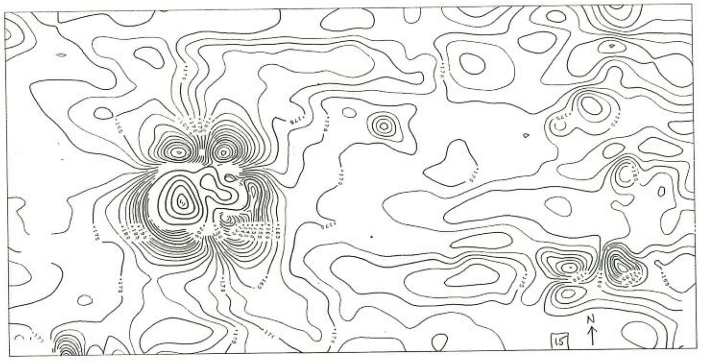
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FIGURE CAPTIONS

Fig. 1. MASCA cesium magnetometer in use at San Lorenzo.

Fig. 2. Varian Associates audio cesium magnetometer in use at San Lorenzo.

Figs. 3. & 4.

Fig. 3. Map of locations of magnetometer surveys overlain on

Fig. 4. Map of San Lorenzo site made by G.R. Krotser, 1967 edition.

Notes: Outlines and numbers of magnetometer grids are shown. Hatched regions are areas which were covered with the audio cesium magnetometer without laying out grids.

The two maps were related by the benchmarks as designated by M, N, X symbols.

Fig. 5. Magnetometer Grid #22.

Fig. 6. Magnetometer Grid #19.

Fig. 7. Magnetometer Grid #5.

Fig. 8. Olmec head, Excavation 2-69, Grid No. 9.

Fig. 9. Magnetometer Grid #9.

Fig. 10. Magnetometer Grid #13.

Fig. 11. Magnetometer Grid #14.

Fig. 12. Magnetometer Grid #17.

Fig. 13. Column, Excavation 6-69, Grid #17.

MAGNETOMETER SURVEY
AT SAN LORENZO, MEXICO

Winter, 1969

by

Elizabeth K. Ralph

The Olmec site of San Lorenzo Tenochtitlan in the state of Veracrux, Mexico is a suitable one for the detection of ancient monuments with magnetometers because of the fortuitous fact that the Olmecs imported massive basaltic rocks from 80 km away for their construction. Also, this basaltic rock does not occur naturally at the site. Samples of the rocks and earth were first collected by Dr. Froelich Rainey (Director of the University Museum, University of Pennsylvania, Philadelphia) in 1967. These were tested for their magnetic susceptibilities and it was found that the basaltic rocks were extremely magnetic and that the natural earth contained negligible magnetism. These measurements indicated that it should be quite possible to detect all of the ancient monuments with magnetometers.

In collaboration with Dr. Ignacio Bernal (Director of the Instituto Nacional de Antropologia, Mexico), initial trials at the site were conducted in March 1968 on behalf of the Museum Applied Science Center for Archaeology (MASCA) of the University Museum by Dr. Sheldon Breiner and Marvin Harris of Varian Associates (Palo Alto, California). These were extremely successful and in a few weeks of field work 40 anomalies were detected and 4 were confirmed by excavation.

The site of San Lorenzo is not new to archaeologists and has been excavated extensively by Mathew Sterling, Philip Drucker, Michael D. Coe, Richard E. Diehl, Paula Krotser, Ramond Krotser and Francisco Beverido. However, it was decided that a comprehensive systematic magnetometer survey should be conducted over the entire site to locate all of the remaining monuments. Therefore, the mutual collaboration between the Instituto Nacional and the University Museum was continued in February and March, 1969. The field surveys were conducted by Elizabeth K. Ralph (Associate Director of MASCA) and John Parker (Varian Associates). The Campamento de San Lorenzo was organized and the test excavations were supervised by Francisco Beverido (Instituto de Antropologia de Veracruz and INAH) and assisted by Roberto Gallegos (Ins. Nacl. A.H.).

Two types of cesium magnetometers, (both manufactured by Varian Associates) were used. The basic components of each are a readout and a cesium sensor and both are powered by 30 volt batteries (see Figs. 1 & 2). The designs of the two readouts are quite different. The larger and more sensitive readout is the Model 49-116 which was designed especially for MASCA and was first used in the search for Sybaris in southern Italy (Rainey and Lerici, 1967). With a single sensor, its maximum sensitivity is 0.1 gamma (10^{-6} oersted). It also contains a difference circuit so that two sensors can be used and it is possible to read only the difference between the two. The second sensor, if placed in a fixed position or in a gradiometer arrangement, serves to cancel out external (or diurnal) magnetic changes so that the full sensitivity of the instrument can be utilized. The features and operation of this magnetometer have been described by Ralph, Morrison, and O'Brien (1968). The difference mode of operation was tried in grids #4 & 5, but it was found that the anomalies at San Lorenzo were sufficiently large so that maximum sensitivity was not required and that the diurnal changes could be ignored. For more practical reasons, its use here was slower because the brush and trees caused difficulties with the long cable leading to the second sensor in a fixed position in the center of the grid. Also, in the midst of grid #5, the second sensor ceased to function. Therefore, subsequent grids made with the Model 49-116 (labeled MASCA Cs on the grids) were with a single sensor and readings appeared in digital form directly in gammas.

The second type of readout (labeled Audio Cs on the grids) is smaller and is not calibrated directly in gammas. It contains a variable oscillator with a scale of 1000 units attached to the variable control knob. In use, the frequency of this oscillator is varied to match the Larmor precession frequency from the cesium sensor. The match is made by obtaining an audio null, or zero beat frequency, and then the dial is read. Each unit on the dial is roughly equivalent to 1½ gammas. This readout is the more suitable of the two for rapid exploration and for pin-pointing the centers of anomalies when it is not necessary to take readings. For doing precise grids, however, the MASCA Cs readout is more rapid to use because there is no need to adjust a dial to take a reading. An experimental dual audio readout system was provided by Varian Associates for trials at this site, but for various reasons, this system did not work. Therefore, except for grid #4 and part of #5, all grids were made with single sensors.

The procedure in the field was to measure out the base lines of each grid with tape measures and to place stakes at 10-meter intervals. (Where possible, the grids measured 100 by 100 meters.) Then for each grid a 100-meter rope, marked at 2-meter intervals, was strung between the first stakes of the base lines. The man carrying the sensor then moved along the rope, pausing at each 2-meter marker while a reading was taken by a second operator carrying a readout and batteries. Then successive parallel lines were made at two-meter intervals. It was possible for the sensor-man to see the rope markers from a distance of 4 meters so that the rope could be advanced at intervals of 10 meters instead of for every line. Each reading was recorded in a notebook orientated in the same direction as the grid was traversed. At completion, the pages of the notebook were pasted together to form the whole grid.

The locations of the magnetometer grids are shown in Figure 3. When this figure is overlain on the excellent map of the site made by G. R. Krotser (Fig. 4) the relationship between the grids and the features of the site can be seen. The grids in Fig. 3 have been located approximately, but the significant anomalies, more precisely by triangulation. Unfortunately, our main baseline running south from benchmark M3 went askew as we passed over mound 1 before a surveyor's transit was available. Therefore, there is some uncertainty about the locations and exact shapes of grid numbers 10, 11, 13, 15, and 16.

The results of this magnetometer survey are summarized in Table 1, and some of the grids are illustrated in Figs. 5 to 13. In these grids, the line numbers referred to in Table 1 are labelled at the bottom of each. The anomalies are regions of closely spaced contours of equal magnetic intensity. In most cases, contours have been drawn at intervals of 10 gammas (or units). Grid #22 (Fig. 5) is an example of one with no anomalies. It contains a few wiggly contours which represent only natural subsurface or possibly small diurnal changes. The base reading in this and other grids made with the MASCA Cs readout was 43100 gamma, but to save time and space, only the last two digits were recorded. A contour labelled 70, for example, is actually 43170 gamma. Grid #19 (Fig. 6) shows an example of a small doubtful anomaly centered on line 10. It has an intensity of 100 gamma above the base reading, but only in one reading. To the right of this (north in this case) there is a small anti-magnetic reaction represented by a few contours of lower than normal magnetic intensity. Pronounced diurnal changes are also illustrated in this grid by the long, mostly straight vertical east-west contours. These could be eliminated and corrected for by reference readings taken regularly at a fixed position, but since there is no confusion between these long vertical lines and the true anomalies, this extra work is not necessary. Six anomalies were tested by excavation. The anomaly of Grid No. 5 (Fig. 7), excavation No. 1-69 is similar to that of Grid No. 19 and it was a true anomaly in that it represented basaltic rocks, but only a jumble of small ones. The first exciting find was a large Olmec head, 2.55 meters long (see photo, Fig. 8). This anomaly was detected in Grid No. 9 (Fig. 9). The anomaly is again small in area due to the shallow depth (46 cm) of the monument, but it does contain one very magnetic reading (over 120 units) and two anti-magnetic. In this same grid, the doubtful anomaly in line 2 was excavated (No.3-69) and nothing was found. Presumably then other similar doubtful anomalies of less than 50 gammas can be ignored. The anomaly of Grid No. 13 (Fig. 10) which continues in the adjoining Grid #11 seemed to be more extensive and had a maximum intensity of over 150 gamma, but in a large test excavation (No. 4-69), no basaltic rocks were found. Some reddish and possibly magnetic earth was removed which may account for the anomaly. We are quite sure that the feature could not have been deeper or missed laterly because after the excavation, the anomaly disappeared.

In Grid No. 14 (Fig. 11) many anomalies were, at last, detected. The most pronounced one centered on line 0 was so intense that it was not possible to draw all of the contours at 10 gamma intervals at the grid scale of 1:200. These have, therefore, been drawn at intervals of 50 gamma at a scale of 1:100 as shown in the insert (Fig. 11). Excavation No. 5-69 indicates that these anomalies represent the area of an Olmec workshop.

In Grid No. 16 it was not really necessary to use a magnetometer to find a relatively small torso lying on the surface, but it did produce a magnetic anomaly. Grid No. 17 (Fig. 12) contains two anomalies. Excavation No. 6-69 revealed that the more intense one (lines 48 and 50) was caused by a massive column, probably more than two meters long, lying on its side at a depth of 50 cm. (See photo, Fig. 13).

Summary

In six weeks, over 200,000 square meters were covered in 31 complete grids with readings taken at every 2 meters. It is possible that small monuments at depths of less than 1 meter were missed in the regions covered by grids, but unlikely that large ones have been. In addition, fringe areas and some steep slopes were covered with the Audio Cs (as designated by the hatched areas in Fig. 3) without laying out grids and recording readings. Thirteen grids contained no anomalies. In others 12 doubtful anomalies were detected and 13 good ones. From the test excavations, completed as of March 29, 1969, there were three significant finds - the head, the column, and the workshop.

When on compares these results with the many monuments found in the past as shown on Krotser's map (Fig. 4), one wonders why more were not found with the magnetometers. The most logical explanation seems to be that the site has been excavated so extensively both by archaeologists and by the local population of nearby San Lorenzo Tenochtitlan, that little reamins to be found. Many of the large excavations are still in evidence and in addition, as one walks over the ground all day taking magnetometer readings, one encounters the many small pits made by the "clandestinos."

(Continue to next page for Postscript)

Postscript

A letter from Francisco Beverido Pereau dated April 9, 1969 has just been received from San Lorenzo, and he reports on subsequent excavations as follows:

1) The second anomaly in Grid No. 17, (the grid with the column, excavation 6-69) produced nothing.

2) The anomaly in Grid No. 31 near the Trough Stones represented a stela of green stone harder than serpentine. It is 5.35 m long and 60 cm in diameter and has a light relief that is typically Olmec.

3) The anomalies of Grid No. 18 are both significant. The easternmost one (near the edge of the grid) represented a column of basalt 1.8 m long by 80 cm in diameter, located vertically and associated with two other artifacts of stone in the manner of chairs. The anomaly in the western part of the grid produced a beautiful rectangular plaque, 1 m long and 80 cm wide and 25 cm thick with a low relief similar to the stela found by Michael Coe two years ago in the same location.

This good news from San Lorenzo now brings the total of finds to six, some of which are extremely interesting.

REFERENCES

F. G. Rainey and C. M. Lerici, 1967, The Search for Sybaris, 1960-1965, Lerici Editori, Rome.

E. K. Ralph, F. Morrison, and D. P. O'Brien, 1968, Archaeological Surveying Utilizing a High Sensitivity Difference Magnetometer. Geoexploration, Vol. 6, pp. 109-122.

Table 1. Summary of Magnetometer Survey, Winter 1969

Grid No.	Magnetic Anomalies	Results of Excavation or Interpretation
1	1 doubtful (line 20)	
2	none	
3	none	
4	none	
5	1 good (line 34)	No. 1-69. Consisted of approximately 20 basaltic rocks averaging 2-3 kg. each and found at a depth of about 45 cm.
	1 doubtful (line 60)	
6	none	
7	none	
8	small anomalies in southwest corner	Area of anomalies was recovered in G#14.
9	1 good (lines 8 & 10)	No. 2-69. Large Olmec head, approximately 2.55 m long, lying on its back side, at depth of 46 cm.
	1 doubtful (line 2)	No. 3-69. Nothing found in excavation.
10	1 doubtful (line 34)	
11	1 good (SW corner)	Anomaly at border of G11 & G13, but more pronounced in G13.
12	none	
13	1 good (SE corner)	No. 4-69. No basaltic rock found, but there was reddish earth which was probably magnetic
14	1 large & intense and many smaller ones surrounding it	No. 5-69. Appears to be the site of an Olmec workshop and contains many basaltic rocks.
15	1 large & intense (lines 20 to 30)	Anomaly previously detected by S. Breiner in 1968. Excavation revealed massive stone slab.
	1 doubtful (line 38)	
16	1 small (line 84)	Small torso found on surface of the ground.

Table 1. Continued

Grid No.	Magnetic Anomalies	Results of Excavation or Interpretation
17	1 very intense (lines 48 & 50)	No. 6-69. Large column, at least 2 m long, lying on side at depth of 50 cm.
	1 less intense (near old excavation pit)	
18	1 very intense (east end line 36)	
	1 less intense (west on lines 36 & 38)	
	1 intense but small (line 22)	Large stone, excavated previously.
	Several additional doubtful ones	One visible rock. No anomaly from visible section of drain.
19	1 doubtful (line 10)	Example of unusually large diurnal changes.
20	1 small (line 36)	Two meters away from large slab excavated previously.
21	none	
22	none	Example of negligible diurnal changes.
23	none	
24	none	
25	none	
26	none	Very small reaction of small excavated monument.
27	1 doubtful (line 18 W)	
28	none	
29	1 doubtful (line 10)	
30	none	
31	1 good	

FIGURE CAPTIONS

Fig. 1.	MASCA cesium magnetometer in use at San Lorenzo.
Fig. 2.	Varian Associates audio cesium magnetometer in use at San Lorenzo.
Figs. 3. & 4.	
Fig. 3.	Map of locations of magnetometer surveys overlain on
Fig. 4.	Map of San Lorenzo site made by G.R. Krotser, 1967 edition.
Notes:	Outlines and numbers of magnetometer grids are shown. Hatched regions are areas which were covered with the audio cesium magnetometer without laying out grids. The two maps were related by the benchmarks as designated by M, N, X symbols.
Fig. 5.	Magnetometer Grid #22.
Fig. 6.	Magnetometer Grid #19.
Fig. 7.	Magnetometer Grid #5.
Fig. 8.	Olmec head, Excavation 2-69, Grid No. 9.
Fig. 9.	Magnetometer Grid #9.
Fig. 10.	Magnetometer Grid #13.
Fig. 11.	Magnetometer Grid #14.
Fig. 12.	Magnetometer Grid #17.
Fig. 13.	Column, Excavation 6-69, Grid #17.

Table 1. Summary of Magnetometer Survey, Winter 1969

Grid No.	Magnetic Anomalies	Results of Excavation or Interpretation
1	1 doubtful (line 20)	
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4	none	
5 (See Fig.)	1 good (line 34)	No. 1-69. Consisted of approximately 20 basaltic rocks averaging 2-3 kg each and found at a depth of about 45 cm.
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6	none	
7	none	
8	Small anomalies in southwest corner	Area of anomalies was recovered in G#14.
9 (See Fig.)	1 good (lines 8 & 10)	No. 2-69. Large Olmec head, approximately 2.55 M long, lying on its back side, at depth of 46 cm.
	1 doubtful (line 2)	No. 3-69. Nothing found in excavation
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13 (See Fig.)	1 good (SE corner)	No. 4-69. No basaltic rock found, but there was reddish earth which was probably magnetic.
14 (See Fig.)	1 large & intense and many smaller ones surrounding it	No. 5-69. Appears to be the site of an Olmec workshop and contains many basaltic rocks.
15	1 large & intense (lines 20 to 30)	Anomaly previously detected by S. Breiner in 1968. Excavation revealed massive stone slab.
	1 doubtful (line 38)	
16	1 small (line 84)	Small torso found on surface of the ground.
17 (See Fig.)	1 very intense (lines 48 & 50)	No. 6-69. Large column, M long, lying on side at depth of
	1 less intense (near old excavation pit)	
18 (See Fig.)	1 very intense (east end line 36)	
	1 less intense (west on lines 36 & 38)	
	1 intense but small (line 22)	Large stone, excavated previously
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19 (See Fig.)	1 doubtful (line 10)	Example of unusually large diurnal changes.
20	1 small (line 36)	Two meters away from large slab excavated previously
21	none	
22 (See Fig.)	none	Example of negligible diurnal changes.
23	none	
24	none	
25	none	

24	none	
25	none	
26	none	Very small reaction of small excavated monument
27	1 doubtful (line 18 W)	
28		
29	1 doubtful (line 10)	
30	none	
31	1 good	

p. 7 bottom (Continue to next page for Postcript)

Postcript

A letter ~~has just~~ dated April 9, 1969 has just been received from San Lorenzo, from Sr. Francisco Beverido Pereau & he reports on subsequent excavations as follows:

1) The ~~an~~ second anomaly in Grid No. 17, (the grid with the column, excavation 6-69) produced nothing.

2) The anomaly in Grid No. 31 near the Trough Stones represented a stela of green stone harder than serpentine. It is 5.35 m long and 60 cm in diameter & has a light relief that is typically Olmec.

3) The anomalies of Grid No. 18 are both significant. The easternmost one (near the edge of the grid) represented a column of basalt 1.8 m long by 80 cm in diameter, located vertically & associated with two other artifacts of stone in the manner of chairs. The anomaly in the western part of the grid produced a beautiful

rectangular plaque? ~~stock~~, 1 m long and 80 cm wide and 25 cm thick ____ with a low relief similar to the stela found by Michael Coe two years ago in the same location.

This good news from San Lorenzo now brings the total of finds to six, some of which are extremely interesting.

geoMetrics

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Palo Alto, California 94303
(415) 321-7610

Remote Sensing and Interpretation

October 7, 1969

Dr. Froelich Rainey
Director
The University Museum
University of Pennsylvania
23rd & Spruce Streets
Philadelphia, Pennsylvania 19104

Dear Fro:

We have finished the computer processing and machine contouring of the San Lorenzo data received from you this past May. I had originally estimated that the work would be finished by approximately mid-July, but the job entailed far more computer program development, actual computer time and man-weeks of work than I had anticipated. Thanks largely to the efforts of Alan Edberg, Lauralee Sabo and Doug O'Brien, the results were, I think, fairly impressive, as you can see by comparing these maps, sent already under separate cover, with the original maps contoured by hand last spring.

The procedures we followed in generating these maps were as follows:

1. <u>Transfer of Data to Punch Cards</u>

   The data values for all 31 grids, approximately 80,000 grid points, were first punched on cards. These cards were then processed by the computer to produce a paper printout of the values in the original grid format. These values were then visually compared with the original hand-drawn values for verification and corrected for erroneous readings or card punch errors.

2. <u>Removal of Time Variations</u>

   Next the average value for each profile line was computed. The time or diurnal variations were then removed by adding or subtracting a value from each data point equal to the amount by which the average value for that particular profile line differed from an arbitrary datum level established for that entire grid. On five grids the average values of some of the lines were unfavorably biased by large anomalies. In those cases, the average values for the lines were selected as the average value of non-anomalous neighboring lines.

3. Computed Upward Continuation

The values, thus adjusted to a common reference level, were then processed by a sophisticated program, derived from the laws of potential field theory, which computed the values that would have been observed at a level one meter higher than the actual elevation of the sensor. The purpose of this procedure was to reduce the effects of the digital noise level of the readings; decrease the effects of surface magnetic noise; and smooth the very sharp gradients one observes while walking relatively close to shallow anomalies. The result was that an anomalous reading at but one data point was now expressed at several data points with a slightly reduced maximum value. In the original hand-drawn map where a single data point was contoured with no anomalous contours at adjacent points the significance of that single data point was questionable, particularly when at the noise level or when the data point happened to be the value of a contour line. This upward continuation process takes advantage of the subtle changes in neighboring values which in the original hand-drawn map were, for several reasons, not contoured.

4. Bicubic Spline Data Point Generation

The original data values were spaced two meters apart comprising a total of 80,000 grid points which when contoured directly, represented a somewhat jagged, discontinuous and difficult to interpret surface. Holding constant the values of the 80,000 computed points, additional points were then computed using a mathematical technique known as a bicubic spline. A total of 500,000 points were thus established. The data points thus generated were spaced one-half meter apart and observed theoretically at an elevation of approximately 1.6 meters above the ground (0.6 meters while carried plus 1 meter through upward continuation).

5. Computation of Contour Lines and Plotting Machine Commands

Using these 500,000 points, the data were then contoured at a contour interval of 2.5 gammas at a scale of 1" = 10 meters, a scale identical to the original one supplied to us. Automatic suppression of contour lines in regions of very high gradient was also employed to keep the map visually interpretable and yet still portray those small anomalies in extremely low gradient areas. Bold contours were used for the 5 gamma contour interval and very bold contours at the 50 gamma interval.

6. Automatic Machine Plotting

The final maps were generated by a unique computer plotting device, the electrostatic plotter. [This device printed the average sized grid in approximately 1 to 2 minutes, as opposed to the usual 30 to 45 minutes on a digital incremental plotter normally used in computer-generated machine contour plotting.]

The maps thus generated are clearly superior to the maps that were hand-drawn. The large diurnal variations were almost entirely removed, thus allowing one to observe the more subtle anomalies. The actual anomalies were more clearly represented by several contour lines and over more than a single data point, thus emphasizing their presence and establishing confidence in their validity. The contours were expressed throughout the map at a much more precise contour interval while retaining the readability of the contour map itself. More anomalies are visible on the machine contoured map than are visible on the hand-drawn map in many of the grids as can be adjudged by the attached summary.

only 11 more doubtful ones

I would suggest that you take the maps sent to you and photographically reduce and print them. Then on one copy simply color the anomalies you consider significant and use these maps to aid the archaeologist at the site. The location of these grids is the same as that of the original maps and thus no location legend is placed on the grids. The orientation of the grids is self-evident when compared with the original grids. You may wish to supply one standard legend with each grid when photographing the grids for reduction and printing.

We are supplying within the next two weeks 2 three-dimensional perspective views of selected portions of anomalies, one from grid 15 showing the altar and a less spectacular section of another grid. The perspective view of a total intensity map used for mineral prospecting is shown on the enclosed brochure which you may best view by opening the brochure to view at one time both the front and back pages. You will note that it is considerably easier to observe the anomalies, both the major ones and the subtle ones, and to discern trends. Furthermore, almost the entire significance of the map can be grasped immediately even by an untrained person when portrayed as the perspective view. These views are without question impressive to all who see them. These two perspective views will be included at no cost. We would be interested in hearing, however, as soon as possible, whether you have any further interest in producing any more copies of the maps or in acquiring additional perspective views. We presently have approximately 60 magnetic tape reels tied up for this project alone which we must erase as soon as possible for use on other jobs.

My original cost estimate for this job was $2000, but I had asked you to sign my letter of May 29th authorizing an expenditure of as much as $3000 on this job. I regret to say that I have already received strong reprimands by our business manager because this job cost us over $5000 already. I would appreciate payment of $3000 on the job, the remaining loss I am justifying on the basis of its promotional value as outlined in the following paragraph.

I suggest that we both utilize the excellent results I feel we obtained through:

1. A simple press release primarily for the "Trade Journal type of publication" discussing the computer aspects of these archaeological data and the results that can be obtained using the latest magnetometer equipment, modern computer programs and new plotting techniques all designed for geophysical exploration.

2. Publication of these results in three articles -

   a) Your MASCA Newsletter (perhaps the October issue) written by Beth Ralph.
   b) An article for publication on the computer aspects of these data written by Doug O'Brien and Alan Edberg, and
   c) An article on the archaeological exploration of 1968-69 written by Beth Ralph and Sheldon Breiner (and Mike Coe, if appropriate).

Each article would be submitted where appropriate. We would like to suggest the format of the information we would like to see in print with respect to the press release by sending you a rough draft sometime during the next couple of weeks.

I trust you will be pleased with the results of our work and the future potential of performing such work on other data. You will note that only one sensor is needed particularly if you established one or two tie lines across the profile lines and reduce the data using such computer methods. I think the results will be outstanding and much more usable by the archaeologist. Obviously you have a much enhanced promotional benefit from performing such procedures on your data also. I surmise that cost will determine whether or not you employ such computer processing in the future. In this vein let me also clarify the price picture somewhat to say that our price in the future for a corresponding amount of data points would probably have to be twice that which we asked for this amount of work.

Thank you for your patience in awaiting our results. I look forward to discussing the various points I brought up in this letter.

With best regards,

Sheldon Breiner
President

SB:sk
Enclosures

cc: Beth Ralph

d = doub

g = good

San Lorenzo Computer Interpretation of Magnetic Survey Data

Grid No.	Number of Distinct Anomalies Identified by one observer (S. Breiner) Hand-Drawn Map	 Computer-Drawn Map	E. Ralph No. Anomales Valid on basis of Excavation tests on some →
1	3	5	3 d.
2	2 none	0 ?	none
3	1 none	3	none
4	3 none	6	1g, 1d
5	4 1g. 1d.	6	1g, 1d.
6	0	0	
7	1 none	1 none	
8	11 repeated in G14	15 repeated in G 14	
9	3 1g, 1d	5 1, g, 1d. – nothing in excav.	
10	11 1d.	13 –4 d.	
11	11 1g	11 1g, 1d.	
12	4 none	5 none	
13	6 1g	10 1g, 2d.	
14	61 20g	74 20g.	
15	6 1g	8 1g	
16	1 2d	1 2d	
17	5 1g, 1d	8 1g, 1d = nothing in excav.	
18	12 3g, 2d	14 3g, 2d	
19	5 1d	4 2d	
20	2 1 small	5 1 small	
21	3 0	5 good tie sample 0	
22	0	1 ?0	
23	2 0	4 2 d.	
24	2 0	3 0	
25	2 0	2 1d.	
26	3 0	3 0	
27	3 1d	4 1d	
28	0	0	
29	1 1d	1 1d	
30	1 0	1 0	
31	-- 1g	not done	

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Obsidian Trade at San Lorenzo Tenochtitlan, Mexico

Robert H. Cobean, Michael D. Coe, Edward A. Perry, Jr.,
Karl K. Turekian, and Dinkar P. Kharkar

Obsidian Trade at San Lorenzo Tenochtitlan, Mexico

Analysis of obsidian artifacts emphasizes the role of trade in the rise of Olmec civilization.

Robert H. Cobean, Michael D. Coe, Edward A. Perry, Jr.,
Karl K. Turekian, and Dinkar P. Kharkar

The Olmec civilization is now recognized as the earliest complex culture in Mesoamerica, if not in the entire pre-Columbian New World. This civilization is pristine, in the sense of having been the first to appear in the area and of having developed its major traits in virtual isolation. In this way, it is comparable to pristine civilizations of the Old World, such as the Shang in China or the Sumerian in Mesopotamia. Archeological excavations and radiocarbon dating have shown that the Olmec civilization flourished in the hot, wet lowlands of the Mexican Gulf Coast, from about 1150 to 400 B.C., many centuries before the appearance of other complex cultures in Mesoamerica.

Perhaps one of the most significant facets of the rise and evolution of a pristine civilization is its trade and procurement systems. These systems are revealed either by the identification of manufactured articles that are typical of other sites, or by the identification of raw materials from sources that have unique chemical or physical properties.

In Mesoamerica, as in the Mediterranean and Near East, obsidian trade prospered. Dixon, Cann, and Renfrew (*1*) have used the concentrations of trace elements in obsidian to determine sources in the latter two areas. Obsidian trade, if it is significant, acts as an indicator of general trade and procurement during a particular time.

The importance of obsidian for the economy of ancient Mesoamerican peoples was probably similar in magnitude to that of steel for the economies of modern industrial nations, for the Mesoamerican peoples manufactured most of their tools and weapons either from or with obsidian and no doubt considered it a necessity for existence. Because the overwhelming majority of nonceramic artifacts in Mesoamerican sites are made from obsidian, it has become obvious (*2*) that an analysis of the sources of obsidian should indeed throw great light upon ancient trade and procurement systems in Mesoamerica.

The oldest Olmec site so far recognized is San Lorenzo Tenochtitlan, which is actually a complex of three sites in southern Veracruz, Mexico, near the middle reaches of the Coatzacoalcos River. Three field seasons of work conducted by Yale University and the Instituto Nacional de Antropología e Historia (*3*) have demonstrated that the San Lorenzo site itself, a partially man-made plateau lying about 50 meters above the surrounding plains, may well represent the oldest civilized community in Mesoamerica. During its apogee, which was in the San Lorenzo phase (1150 to 900 B.C.), almost all of the famous Colossal Heads and other gigantic basalt sculptures were carved.

The large number of obsidian artifacts recovered at the San Lorenzo site (7747 pieces from unmixed deposits) indicates the importance of obsidian in the inhabitants' economy. Distinctive identifying criteria, especially the concentration of trace elements in obsidian, can be used to assess a population's changing patterns of obsidian acquisition.

Obsidian does not occur naturally in the Olmec "heartland" proper; thus its presence at an Olmec site indicates that it was imported, either through trade or direct procurement. Obsidian was present throughout the long and complex sequence at San Lorenzo Tenochtitlan (*4*), although in differing quantities for each phase. During the first known occupation of the San Lorenzo site (Table 1), in the Ojochi phase (circa 1450 to 1350 B.C.), there are only small, crude flakes in small amounts. The succeeding Bajío (1350 to 1250 B.C.) and Chicharras (1250 to 1150 B.C.) phases show a slight decrease, then increase, in the importation of obsidian. Blades do not occur in any significant amount until the first purely Olmec occupation, which was in the San Lorenzo A subphase (begun by 1150 B.C.). There is a vast increase in the importation of both blades and flakes in the San Lorenzo B subphase, which ended in the partial destruction of San Lorenzo around 900 B.C. There is a definite decrease in importation during the Middle Formative period (Nacaste and Palangana phases), which follow San Lorenzo B. After a long hiatus, during which the area seems to have been essentially abandoned, came the Toltec-influenced Villa Alta phase (circa A.D. 900 to 1200), which marks another great increase in the importation of obsidian.

Obviously, the amount of obsidian obtained by the residents of San Lorenzo Tenochtitlan reflects, in large part, the size of the population at any given time. An even more reliable population index would be the number of metate and mano fragments, since every household had at least one set of maize-grinding stones. Figure 1 shows that population must have been a significant factor; for instance, the peak of obsidian importation during the Formative period was in San Lorenzo B, which also had the peak population, as determined by the number of manos and metates.

By dividing the number of obsidian artifacts—blades, flakes, or the total—by the total number of metates and manos for each phase, it should be possible to arrive at a rough estimate of the household consumption of obsidian. Figure 2 shows that, with the exception of the aberrant Ojochi phase (the conclusions about which are probably distorted by the small sizes of the samples), there was a net increase in the amount of obsidian used by the households of San Lorenzo Tenochtitlan throughout all of the phases, particularly throughout the Formative period. This may be an indication of the gradual rise in prosperity, or "buying power," of the individual in this part of Mesoamerica; if so, the highest level of prosperity was

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attained by Villa Alta times, in the Early Post-Classic Period. The ability of the local inhabitants to obtain finished obsidian artifacts rather than crude flakes also rose and fell. Because we recovered only 11 definite blade cores, it can be assumed that the majority of the 2796 blades Coe found had been imported as finished products into San Lorenzo Tenochtitlan; thus their presence is a good index to native buying power.

Sampling and Analysis

Obsidian is a volcanic glass that is chemically similar to granite. Obsidian deposits in Mesoamerica (with the possible exception of Guerrero) occur principally in the east-west volcanic cordillera of central Mexico and the highlands of Guatemala. Twenty-five of the sources of obsidian in Mexico and Guatemala were sampled by Cobean in 1969 (Fig. 3).

In the process of collecting samples from the obsidian sources, the entire source area was investigated wherever possible. However, a number of sources, such as Pachuca and the Ixtepeque Volcano, are so extensive that only a small fraction of their vast quantities of obsidian could be surveyed during the same time available. At least three samples were taken from different sections of each source, the weights of the samples varying between 5 and 300 grams.

We selected from the collection recovered at San Lorenzo Tenochtitlan those artifacts within each cultural phase that represented the widest possible differences in color and in surface appearance, in the hopes of thereby obtaining samples from most or all of the obsidian sources used during each phase. We also took great care to select obsidian artifacts from only those archeological deposits that were as free as possible of admixture with materials that had been deposited in earlier occupations of the site.

In one case, for the San Lorenzo A phase, a random sampling was made in addition to the selective sampling based on physical characteristics. The complete contents of one bag, 37 flakes and blades recovered from the same excavation unit in a midden, were analyzed with the aim of providing a statistical picture of obsidian procurement by a particular Olmec household at one point in time.

The obsidian samples were ground and then made into pellets at 25 tons per square inch (6.5 square centimeters). Concentrations of iron, manganese, rubidium, strontium, and zirconium were determined by x-ray emission spectroscopy without the use of matrix corrections, inasmuch as the narrow range of the concentration of major elements in the obsidians was adequately simulated by the U.S. Geological Survey standard granite G-1. The use of strip chart recordings speeded the method and gave a standard deviation of 10 percent. Each obsidian sample was analyzed in duplicate. In addition, 25 of the samples were analyzed in duplicate for manganese and sodium by neutron activation (*5*), which gave a standard deviation of 2 percent. This procedure allowed a finer discrimination where necessary.

Results

The most significant elements in identifying compositional groups are rubidium and zirconium. Figure 4 is a scatter diagram of the artifacts on a zirconium-rubidium plot. Of the 25 sources of obsidian sampled, only eight appear to be represented in the artifacts at San Lorenzo Tenochtitlan. The artifacts that did not come from any one of the eight sources appear to cluster around five to seven other sources, from which we did not take samples. Approximately 83 percent (by weight) of the artifacts we analyzed are from the eight identified sources. The obsidians from each are distinguishable by their appearance, flaking characteristics, and concentrations of trace elements (Table 2).

Table 1. Obsidian sources utilized during each phase at San Lorenzo Tenochtitlan. (Group A, Group B, and so on are compositional groups from unknown sources. Superscripts: 1, projectile point; 2, knife or knife-scraper; 3, graver; 4, flake core; 5, blade core; and 6, nodule.)

Phase	Sources (No.)	Flakes	Blades	Other
Ojochi	3,* *4*†	Guadalupe Victoria Pico de Orizaba El Chayal *Group C′*‡		
Bajío	3, *4*	Guadalupe Victoria Pico de Orizaba Group D *El Chayal*		
Chicharras	3	Guadalupe Victoria El Chayal Teotihuacan		
San Lorenzo A	5	Guadalupe Victoria El Chayal Group A Group E	Teotihuacan Group A Group E	Guadalupe Victoria^{2} Teotihuacan^{1} Group A^{1}
San Lorenzo B	8, *11*	El Chayal Ixtepeque Volcano Pachuca Group B *Group E*	Guadalupe Victoria Teotihuacan Group B Group E *Pachuca* *Ixtepeque Volcano* *El Paraiso* *Group C′*	Guadalupe Victoria^{2} El Chayal ^{1,2,5} Ixtepeque Volcano^{1,6} Group A′ ^{1,2} *El Paraiso*^{1} *Altotonga*^{1,5}
Nacaste	9, *10*	Guadalupe Victoria El Chayal Ixtepeque Volcano Group A *Teotihuacan* *Group C*	Pachuca Teotihuacan El Paraiso Group C′ *Altotonga*	Altotonga^{1} *Guadalupe Victoria*^{3} *Ixtepeque Volcano*^{1}
Palangana	6, *8*	El Chayal *Guadalupe Victoria*	Teotihuacan El Paraiso Group A′ Group C′ *Altotonga*	Guadalupe Victoria^{4} El Paraiso^{1} *Pico de Orizaba*^{3}
Villa Alta	8, *10*	Guadalupe Victoria Pachuca Group B El Paraiso *El Chayal*	Pachuca Teotihuacan Group A Group C *Group B* *El Paraiso*	Pachuca^{1,3} Teotihuacan^{2,3} El Paraiso^{3} Group C ^{3} Group C′ ^{1,3,5} Group A^{5} *Pico de Orizaba*^{5} *El Paraiso*^{5}

* Unitalicized number includes only sources with highly probable identifications. † Italicized number includes tenuous as well as highly probable identifications. ‡ Italicized words indicate a tenuous correlation between the artifact and the given group.

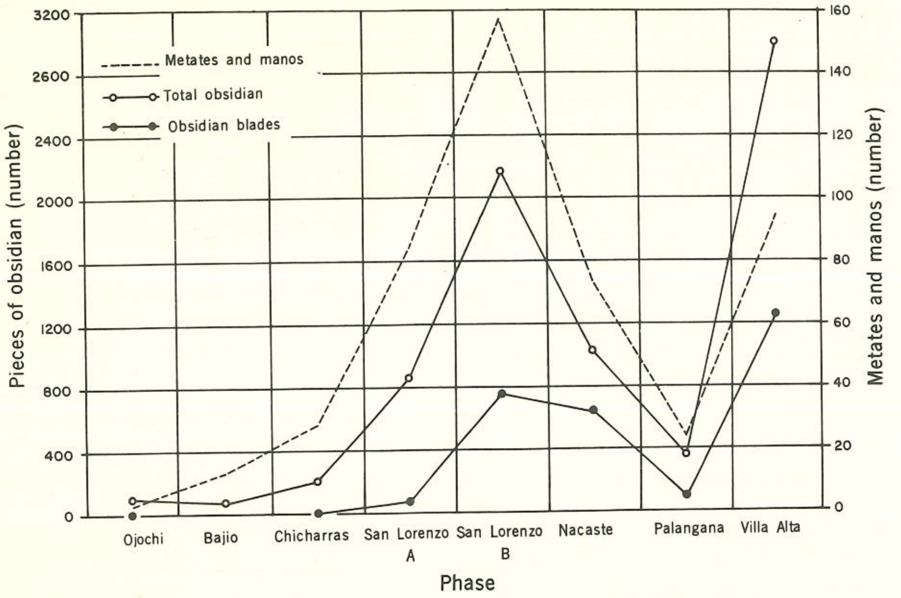

Fig. 1. Occurrence of obsidian artifacts and maize-grinding stones (metates and manos) at San Lorenzo Tenochtitlan, by phase.

Obsidian from the Guadalupe Victoria–Pico de Orizaba area is the only obsidian we found to have zirconium present in trace amounts (< 50 parts per million); it also has distinctive banding. Obsidian from the Pachuca area has more than 600 parts of zirconium per million and a unique green color. Ixtepeque obsidian is distinguished from Teotihuacan obsidian by the concentrations of zirconium and rubidium alone, while the concentrations of manganese and strontium present further differentiate Teotihuacan, El Chayal, and El Paraiso obsidians. Obsidian from Altotonga correlates well with some of the artifacts on the basis of rubidium, strontium, and manganese concentrations, although the concentration of zirconium in the artifacts is in the upper end of the range from that source. This correlation is, thus, less definite than the correlations between the other artifacts and their respective sources. Obsidian from San Bartolomé, Guatemala, was found, on the basis of x-ray fluorescence, to have a composition similar to that of Teotihuacan obsidian, but the high ratios of manganese and sodium in these samples, as determined by neutron activation, allowed us to distinguish between them (the average ratios are 0.0120 and 0.0156, respectively, with no overlap).

A more detailed description of the eight sources follows.

Guadalupe Victoria, Puebla (M-F1, M-F2), and Pico de Orizaba, Veracruz (M-F3): These sources are the products of the Orizaba Volcano, and they lie on its west and east flanks, respectively. The Orizaba Volcano was probably the most important source of obsidian in Mesoamerica during the Formative period, and was in use shortly after 6500 B.C. We have determined that an obsidian point of the Midland type, ascribed to the El Riego phase in Tehuacan, is of the same compositional group as obsidian from the Orizaba Volcano; we thus conclude that Orizaba obsidian was being used shortly after 6500 B.C. Typically, Guadalupe Victoria and Pico de Orizaba obsidian is banded with grey and has a rather irregular surface because of many small inclusions, which give it a poor flaking quality (although the Pico de Orizaba samples appear to be less opaque). Because of their uneven texture, these obsidians are probably unsuitable for making prismatic blades. Only one blade was identified with this source.

Altotonga, Veracruz (M-F4): This is the second closest known source of obsidian to San Lorenzo Tenochtitlan. It lies about 50 kilometers northwest of Jalapa. In a ravine 1 kilometer north of the small town of Altotonga, there are large nodules of dark, translucent obsidian, which are associated with volcanic ash formations. This obsidian has a smooth texture and appears to be of good working quality.

Teotihuacan (M-E4, M-E5): The Arroyo de Estetes on the eastern edge of the Valley of Teotihuacan is the source of the Río San Juan, and in its arroyo an obsidian flow is exposed. It consists of "staircase" formations of black obsidian flows sandwiched between layers of red ash and lava. Cobbles of grey obsidian were found among the exposures of black obsidian. This material has matte bands in reflected light.

Pachuca sources: The obsidian mines in the Sierra de las Navajas north of Pachuca, Hidalgo, were first described

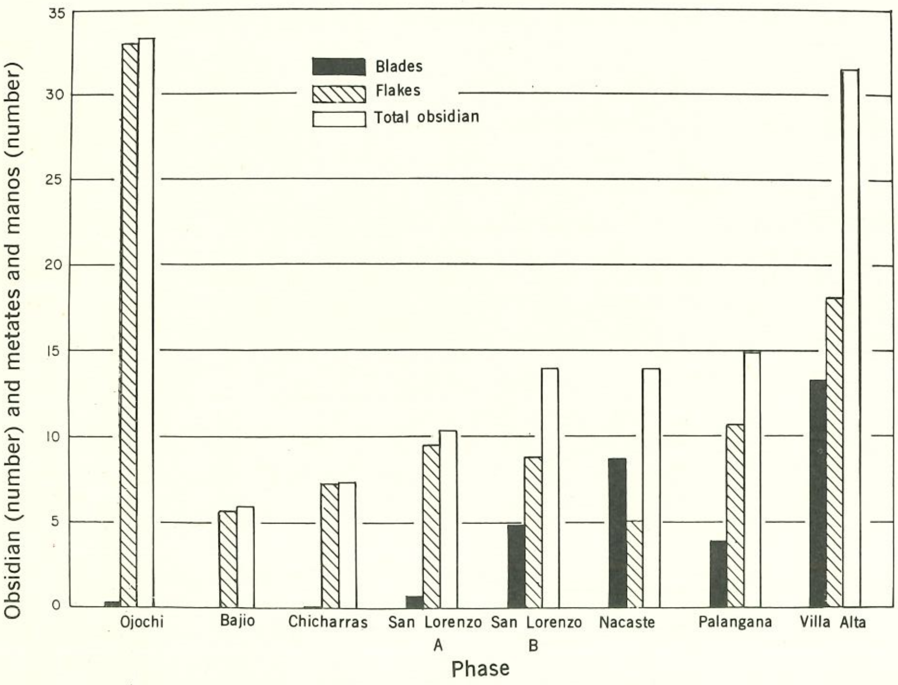

Fig. 2. Ratio of obsidian to metates and manos at San Lorenzo Tenochtitlan. This is by numbers of artifacts, rather than by weight.

by Holmes and recently by Spence and Parsons and by Charleton (*6*). The two localities sampled are Cruz del Milagro (M-E8, M-E9) and El Ocote (M-E10, M-E11), which produce the bottle-green obsidian for which the Pachuca sources are famous. However, in addition to this color, a darker and coarser green was also found.

El Paraiso, Querétaro M-D2): The correlations between artifacts and obsidian from this locality are based on samples from a source about 10 kilometers north of the highway between the city of Querétaro and San Juan del Río, on a ranch near the village of El Paraiso. It is a fine, black obsidian and occurs in outcrops of thin bands separated by layers of ash.

El Chayal, Guatemala (G-C1): This is certainly Guatemala's major source

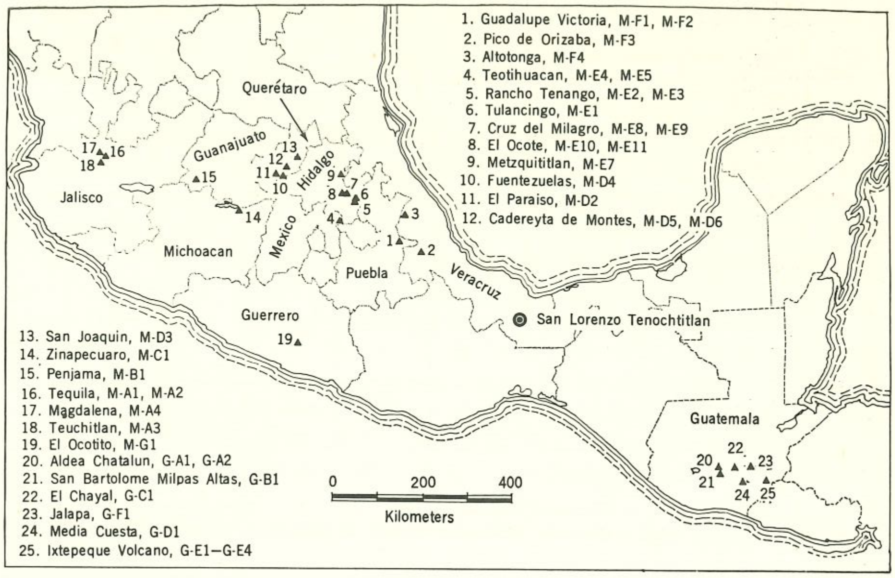

Fig. 3. Mexican and Guatemalan sources of obsidian, sampled during the 1969 and 1970 surveys.

Table 2. Range of the concentrations of trace elements in obsidian groups. (The distinctions between groups A and A′ and between groups C and C′ may be arbitrary, but, in each case, besides the differences in concentration of trace elements, there are consistent differences in color and texture.)

Source—artifact group	Specimens		Range of concentration (parts per million)			
	Source (No.)	Artifact (No.)	Zirconium	Rubidium	Strontium	Manganese
			San Lorenzo artifacts and identified sources			
Guadalupe Victoria, Puebla	5	62	30– 50*	95–130	60– 90	720–1130
Pico de Orizaba, Veracruz	1	2	30– 50*	125–135	30– 50*	~930
Pachuca, Hidalgo	7	13	600–870	175–210	n.d.†	1275–1625
Ixtepeque Volcano, Guatemala	7	12	130–185	95–120	140–170	580– 770
Teotihuacan, Mexico	5	18	115–160	120–150	120–150	535– 675
El Chayal, Guatemala	3	27	100–135	145–190	135–170	840–1130
El Paraiso, Querétaro	3	14	85–130	140–195	n.d.	220– 275
Altotonga, Veracruz	3	7	120–175	155–185	30– 50*	360– 420
			San Lorenzo artifacts with unknown sources			
Group A	0	10	160–195	175–190	n.d.	520– 590
Group A′	0	4	180–190	200–205	n.d.	510– 520
Group B	0	4	95–100	105–120	n.d.	290– 350
Group C	0	10	140–165	130–150	30– 50*	335– 375
Group C′	0	12	150–175	150–175	30– 50*	335– 375
Group D	0	1	30– 50*	100	n.d.	495
Group E	0	5	140–165	155–170	n.d.	520– 610
			Sampled sources not recognized at San Lorenzo			
Rancho Tenango, Hidalgo/ Tulancingo, Hidalgo	2/2	0/0	485–650	130–145	30– 50*	565– 580
Metzquititlan, Hidalgo	2	0	175–180	285–300	30– 50*	205
Fuentezuelas, Querétaro	2	0	70– 80	220–225	n.d.	375
Cadereyta de Montes, Querétaro	2	0	580	180	n.d.	390
San Joaquin, Querétaro	2	0	510	255	n.d.	350
Zinapécuaro, Michoacan	2	0	90	200–210	n.d.	260
Pénjamo, Guanajuato	2	0	470–630	170–190	n.d.	510
Tequila, Jalisco	2	0	200–225	115–125	55– 60	480
Magdalena, Jalisco	2	0	195–230	160–180	n.d.	630– 650
Teuchitlan, Jalisco	2	0	265–460	185–195	n.d.	480
El Ocotito, Guerrero	2	0	100–125	150–170	30– 50*	260
Aldea Chatalun, Guatemala	2	0	110–125	120–130	180–200	650– 680
San Bartolomé Milpas Altas, Guatemala	2	0	120–145	140–145	120–130	660– 750
Jalapa, Guatemala	2	0	120–125	165–180	180	670
Media Cuesta, Guatemala	2	0	130–150	125–135	160–175	710

* Estimated. † n.d., Not detectable (level of detection ~ 30 parts per million).

of obsidian. It is located on a small hill 25 kilometers northeast of Guatemala City (*7*). A road has been cut through part of this hill, exposing quantities of black and grey-striped obsidian nodules. This source ranks with the Pachuca mines as one of the greatest obsidian workshops in the New World.

Ixtepeque Volcano, Guatemala (G-E1 through G-E4): Huge quantities of grey-striped, solid grey, and solid black obsidian, as well as minor quantities of mottled red material, have been produced by this volcano. Extensive workshop areas have been reported (*8*) in the nearby ruins of Papalhuapa.

The artifacts not clearly associated with one of these eight sources cluster into five to seven other compositional groups. On the assumption that these groups represent sources that were not sampled in this study, we use them in discussing the variety and changes of sources of obsidian found at San Lorenzo Tenochtitlan. These are designated A, A′, B, C, C′, D, and E.

Discussion

Olmec civilization at San Lorenzo Tenochtitlan emerged, matured, and then abruptly collapsed (or was destroyed) over a period of 5½ centuries, from the Ojochi through the San Lorenzo B phases. Various aspects of these cultural processes and events are reflected in the patterns of obsidian trade during this period. The number of sources being exploited during each phase (Table 1) greatly increased between the Ojochi phase (four sources) and the San Lorenzo B subphase (probably 11 sources). It is especially significant that most of this increase in trade took place between the San Lorenzo A subphase (five sources) and the San Lorenzo B subphase. The great expansion of the obsidian trade at this point, along with certain other cultural traits that distinguish the San Lorenzo B from the San Lorenzo A subphase, indicates that certain major changes had occurred in the magnitude or the structure, or both, of the Olmec cultural sphere.

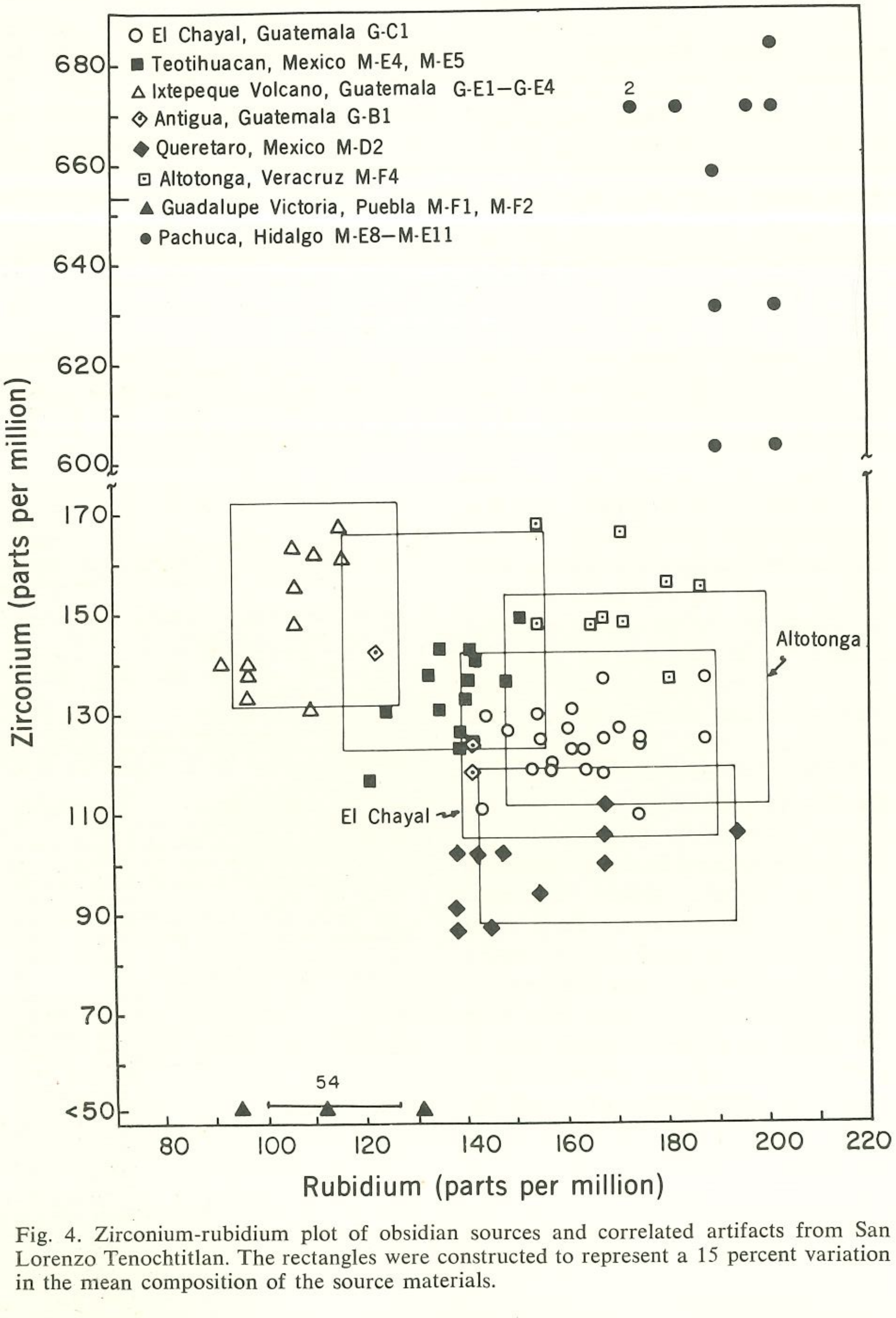

Fig. 4. Zirconium-rubidium plot of obsidian sources and correlated artifacts from San Lorenzo Tenochtitlan. The rectangles were constructed to represent a 15 percent variation in the mean composition of the source materials.

The patterns of obsidian trade show that the Olmec peoples were constantly establishing new commercial relationships with peoples in other areas of Mesoamerica. The importation of obsidian from El Chayal, Guatemala, as early as the Ojochi phase and from Teotihuacan by Chicharras times is especially interesting because it took place several centuries earlier than any known occupations of these source areas, both of which eventually became the centers of great civilizations.

The last line in Table 3 tabulates the number of new obsidian sources that appears in each phase of the archeological sequence, while the other lines record the net gains and losses of sources throughout these phases. The striking expansion of obsidian trade in the San Lorenzo B subphase could have been the result of several cultural processes. It is still uncertain whether the Olmecs developed an empire controlling extensive areas in Mesoamerica outside their heartland on the Gulf Coast; however, the sharp rise in trade and the general elaboration of Olmec civilization during the San Lorenzo B subphase may well have been associated with an empire. Recent archeological research (*9*) has shown that during the Formative period there were strong Olmec influences, and even Olmec trade objects, at many cultural centers beyond the heartland. It has been suggested (*10*) that these influences could have been the result of expeditions or colonization by Olmec merchant-warriors similar to the Aztec *pochteca*.

Our data clearly support the hypothesis that trade played a major role in the expansion of Olmec influence in Mesoamerica, whether or not military con-

Table 3. Appearance and disappearance of obsidian sources exploited by San Lorenzo Tenochtitlan throughout all phases. (All data from Table 2 are included.)

Sources	Phase							
	Ojochi	Bajío	Chicharras	San Lorenzo A	San Lorenzo B	Nacaste	Palangana	Villa Alta
Added	4 (initially)	1	1	2	7	2	2	4
Subtracted	—	1	2	0	1	3	4	2
Net gain or loss	—	0	−1	+2	+6	−1	−2	+2
First appearance of new	—	1	1	2	6	1	0	0

quest played its role too. Religion was another important factor in this process, with many trade activities probably taking place in a religious context. Cults centering upon werejaguars and other Olmec deities spread throughout much of Mesoamerica during the Formative period and appear to have provided the foundations for many aspects of later religions in those regions. Significantly, however, most Olmec cult objects, such as the famous carved jades and the iron-ore mirrors, were made from exotic materials that were procured through trade.

Many of the fundamental patterns and processes in the Olmec economic system cannot be confidently reconstructed at present. For instance, obsidian and other foreign commodities might have been brought to San Lorenzo in several ways. The most likely of these are (i) expeditions in which the Olmecs themselves went to the sources, mined the obsidian, and transported it back to their centers; (ii) ordinary trade, in which the Olmecs exchanged local raw material or manufactured goods for obsidian; and (iii) ritual exchange, in which the Olmecs traded goods or services having mainly religious or symbolic value (but also possessing important economic functions) for obsidian supplied by outside peoples.

The great distance between San Lorenzo Tenochtitlan and most of the obsidian sources makes it highly unlikely that the inhabitants acquired the bulk of their obsidian through mining expeditions. The sources in Guatemala and Hidalgo are more than 800 kilometers by air from San Lorenzo Tenochtitlan and much further by foot or canoe. Thus, the Olmecs must have participated in a trade network with peoples who supplied them with obsidian and other exotic materials. This may have been a ritual exchange system along the lines of the famous *kula* ring of the Trobriand Islands.

Obsidian is the only major, long-distance trade material in the Olmec occupation of San Lorenzo Tenochtitlan that we have been able to associate with specific sources. Petrographic analysis (*11*) shows that basalt for sculptures and for metates and manos was brought in from the Tuxtla Mountains 80 kilometers away, a considerable feat considering that some of the Olmec monuments weigh over 20 tons (18,144 kilograms). While no trade pottery has been found, a wide variety of other exotic goods has; for example, mirrors and beads, possibly of Oaxaca origin, made of polished magnetite, ilmenite, and hematite. Besides the expansion of the obsidian trade in the San Lorenzo B subphase, there was a dramatic increase in the amount of serpentine and flint being imported. Clay figurines of nonlocal design also appear, including some with features vaguely reminiscent of heads from the Valley of Mexico. Other imports in the San Lorenzo phase include fish (red snapper) and bitumen from the coast, along with mica and schist.

Evidence of the kinds of goods that the Olmecs might have exchanged for foreign materials is very incomplete. Workshops engaged in the manufacture of ear spools and beads from serpentine, schist, and other exotic stones were operating in San Lorenzo times. Many of the items exported from San Lorenzo Tenochtitlan, however, must have been ceremonial or prestige objects, such as pottery decorated with Olmec religious motifs, or large, hollow, baby-faced figurines; significantly, these items appear in the rubbish at San Lorenzo Tenochtitlan, whereas in the highland sites of Tlatilco and Las Bocas they were used as grave furniture.

The analysis of obsidian artifacts used during the Formative period in a number of Mesoamerican settlements that show Olmec influences should provide considerably more information on the role of trade in the initial emergence of the Olmec civilization and in the subsequent rise of other Mesoamerican civilizations.

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12. Archeological research at San Lorenzo Tenochtitlan was supported by NSF grant GS-715. We thank José Luis Lorenzo, Francisco Beverido Pereau, Edwin Shook, Francis Gall, G. Van den Boom, Zoltan de Cserna, Laura Flesch, and Terry Stocker for help given R.H.C. on his survey. The geochemical aspects of the research represent a continuum of work on volcanic materials in deep-sea sediments (supported by NSF grants GA-1413 and GA-24155) and in lunar materials (supported by the National Aeronautics and Space Administration.

COVER

Aerial view of the northwestern slopes and foothills of the Pico de Orizaba, (snow-capped mountain on left, 5511 meters) in Mexico. In the foreground can be seen Guadalupe Victoria, principal source of obsidian exploited by the Olmec of San Lorenzo Tenochtitlan. See page 666. [Michael D. Coe, Yale University]

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Magnetic Exploration of the Olmec Civilization

Magnetic surveys have been highly successful in locating Olmec monuments at the site of the oldest known civilization in Mesoamerica

The dream of all archaeologists has been an instrument that would allow them to "see" beneath the surface of the ground, even before excavation. Such an instrument has now been developed and successfully tested in the jungle country of southern Mesoamerica—that region of Mexico and Central America that was civilized before its conquest by the Spaniards.

Sheldon Breiner, geophysicist with GeoMetrics, Palo Alto, California, received a B.S., M.S., and Ph.D. in geophysics from Stanford University. From approximately 1960 his work involved numerous field experiments utilizing the then newly developed high sensitivity alkali vapor magnetometers. His research led to such diverse projects as archaeological prospecting, petroleum and mineral exploration, micropulsation research, avalanche rescue, and earthquake prediction, the last being the subject of his dissertation. He is presently active in developing airborne and marine geophysical survey and interpretation techniques for mineral and petroleum exploration, and is a lecturer and Research Associate in the Department of Geophysics at Stanford University.
Michael D. Coe, Professor of Anthropology at Yale University, received his B.A. (1950) and Ph.D. (1959) from Harvard University. Before coming to Yale, he taught at the University of Tennessee. He is advisor to the Bliss Collection of Pre-Columbian Art at Dumbarton Oaks, Washington, D. C. His research interests are Mesoamerica and the origins of its civilization; recent studies include Maya iconography and cosmology. In connection with his research, he has excavated Olmec sites in southern Mexico and on the Pacific coast of Guatemala. His publications include Mexico *(1962),* The Jaguar's Children *(1965),* The Maya *(1966), and* America's First Civilization *(1968).*
The authors wish to thank Froelich Rainey and Miss Elizabeth Ralph, of the Applied Science Center for Archaeology of the University of Pennsylvania; Ignacio Bernal, of the Instituto Nacional de Antropología e Historia, Mexico; D. P. O'Brien and A. R. Edberg of GeoMetrics; and Varian Associates of Palo Alto, California.
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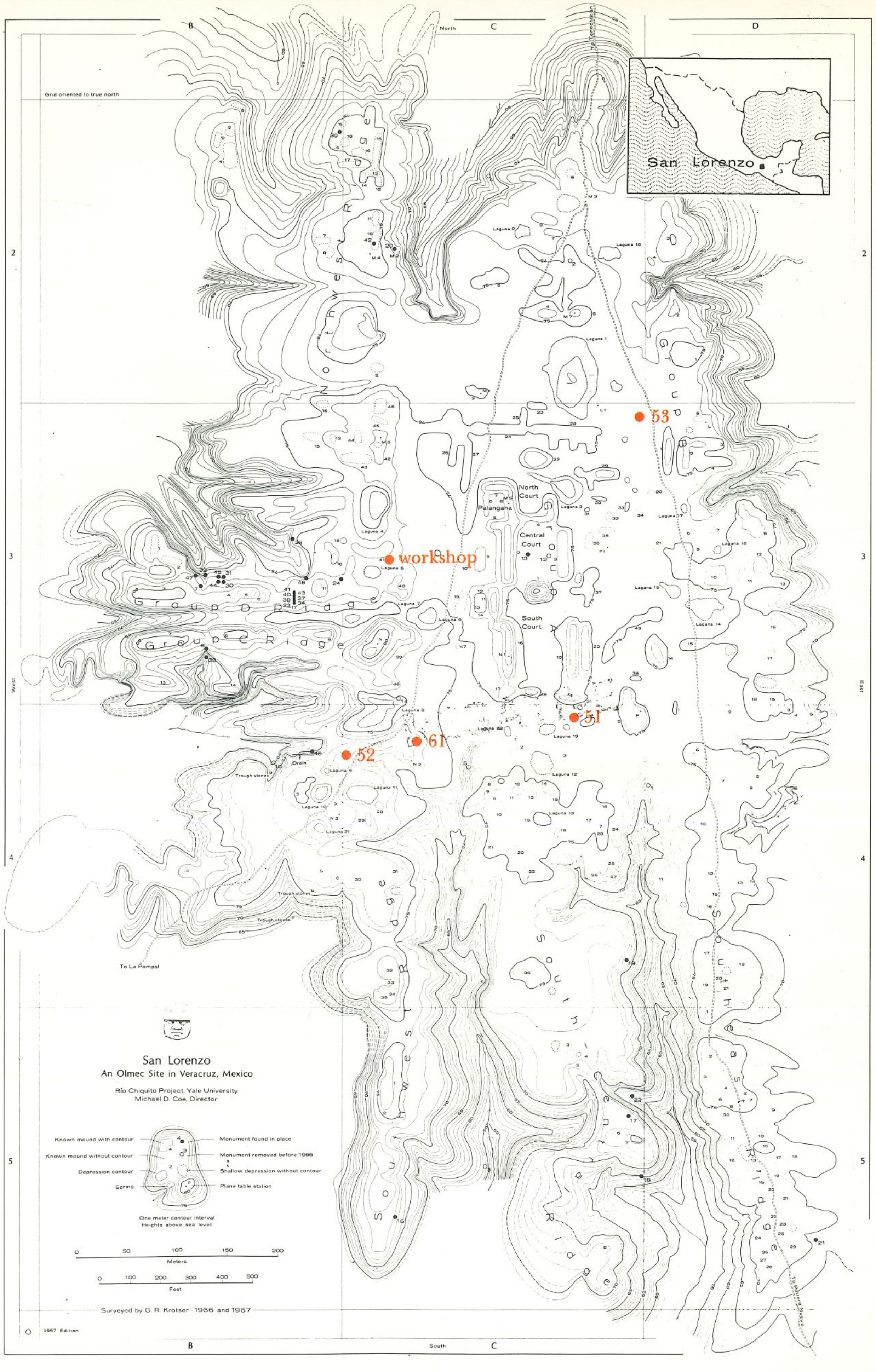
It is now known that the Olmec civilization, dating from approximately 1200 B.C. to 400 B.C., was the earliest of these native cultures (*1*). Most Olmec sites are concentrated in a relatively small heartland along the humid, fertile coastal lowlands of southern Veracruz and Tabasco, but some colonial Olmec centers have been found in the central Mexican highlands and in the state of Guerrero. The primary jungle sites are best known for their magnificently carved monuments, usually made from basalt and weighing up to forty tons. The most striking are the colossal heads—gigantic stone portraits of rulers who are depicted as thick-lipped, flat-faced personages wearing what appear to be helmets. In both the monumental carvings and the finely worked objects of jade and serpentine, the dominant themes seem to be religious symbolization of gods, represented by a combination of the jaguar and the human infant.

Of the four largest Olmec sites in the heartland, the oldest (*2*) now appears to be San Lorenzo, located on a side branch of the Coatzacoalcos River in southern Veracruz (Fig. 1). This center, discovered in 1945 by Matthew W. Stirling (*3*), of the Smithsonian Institution, quickly proved to have the finest and largest Olmec monuments of all. During the two years that he explored San Lorenzo, the carvings were typically discovered either at the bottom of deep ravines cutting into the site or on their slopes. None was found in its original position, and Stirling concluded that they had been pushed over the side by non-Olmec invaders at some unknown time.

Intrigued by the possibilities of throwing new light upon this ancient civilization, Coe (*4*) began in 1966 a long-term investigation of San Lorenzo, under the auspices of Yale University and the Instituto Nacional de Antropología e Historia in Mexico, financed by the National Science Foundation. The first line of inquiry was into the nature of the site itself, which had never been mapped. It was discovered that San Lorenzo was a flat plateau about a kilometer and a quarter long in the north-south direction, with ravines extending from it on the northwest, west, and south sides. Rather than being formed by erosion, the ravines were man-made, resulting from the construction of enclosing ridges, obviously planned. Pairs of them proved to have mirror symmetry, such as a mound on one side being neatly matched by one on the opposite ridge.

Our second discovery, made through ceramic stratigraphy and radiocarbon dating, was that about 900 B.C. a major act of destruction took place at San Lorenzo. Every single piece of carved stone had been mutilated and then dragged onto specially prepared floors built on the ridges, which were completely covered by a fill composed of soil, gravel, and other debris. The monuments that Stirling discovered centuries later in the ravines had simply come to light through the gradual erosion of this fill.

Figure 1. This greatly reduced map of San Lorenzo in southern Veracruz, Mexico, shows the general outline of the plateau with the ridges and ravines. Note the symmetry of the ridges on the south and west sides of the plateau. The monuments indicated by small circles on the map were found before the magnetometer survey. The colored circles show the location of Monuments 51, 52, 53, and 61, which are among the more important objects discovered during the survey.


San Lorenzo
An Olmec Site in Veracruz, Mexico
Río Chiquito Project, Yale University
Michael D. Coe, Director
Known mound with contour
Known mound without contour
Depression contour
Spring
Monument found in place
Monument removed before 1966
Shallow depression without contour
Plane table station
One meter contour interval
Heights above sea level
0 50 100 150 200
Meters
0 100 200 300 400 500
Feet
Surveyed by G. R. Krotser 1966 and 1967
1967 Edition
Grid oriented to true north
North
South
West
East
B
C
D
2
3
4
5
San Lorenzo
Northwest Ridge
Group D Ridge
Group C Ridge
Group B
Southwest Ridge
South Ridge
Southeast Ridge
North Court
Central Court
South Court
Palangana
Laguna 1
Laguna 2
Laguna 3
Laguna 4
Laguna 5
Laguna 7
Laguna 8
Laguna 9
Laguna 10
Laguna 11
Laguna 12
Laguna 13
Laguna 14
Laguna 15
Laguna 16
Laguna 17
Laguna 18
Laguna 19
Laguna 20
Laguna 21
Drain
Trough stones
To La Pompal
To Tenochtitlan
To Potrero Nuevo
workshop
53
51
61
52

The discovery of this pattern of buried sculptures was purely accidental, a piece of luck that occasionally turns up on every expedition. The possibility immediately suggested itself that a great number of other Olmec carvings might still lie under the soil of San Lorenzo. How could these be found? Having had experience in the use of magnetometers for archaeological exploration, Froelich Rainey, Director of the University of Pennsylvania's Applied Science Center for Archaeology, suggested using such instruments at San Lorenzo.

Figure 2. View of the Tuxtla Mountains from San Lorenzo, Mexico. Basalt rock from these mountains was transported approximately 70 kilometers to San Lorenzo, where it was carved into monuments.

Several geophysical techniques based on magnetic, electrical, seismic, or gravimetric methods have been used in archaeological prospecting (*5*). Magnetic surveying has proved to be by far the most practical and useful. Although not a common tool in archaeological kits, magnetometers have been utilized during the past decade at various sites around the Mediterranean (where they helped in finding ancient Sybaris, *6*), in England, and in North America.

Magnetic anomalies at archaeological sites

The magnetic anomalies of significance in archaeological exploration are caused by the contrasting properties of the cultural feature and the soil, water, or rocks covering it (*7*). The amount of the very common mineral magnetite in the feature as well as its mechanical and thermal history usually determine the size of the disturbance, or anomaly, in the earth's magnetic field, which is actually measured by the magnetometer. Various rocks, soils, and objects foreign to the site possess different magnetic properties owing to the widely varying amounts of magnetite and whether or not the magnetic elements of the magnetite grains of the feature are aligned, i.e. the relative proportions of induced and remanent (permanent) magnetism. Buried rocks, walls, artifacts of various types, tombs, trenches, and other such features are all detectable under the right circumstances.

The most prominent magnetic anomalies are usually caused by natural materials that have undergone heating. Clay objects that have been subjected to high temperature, such as bricks, tiles, pottery, and firepits, attain a remanent magnetism as a consequence of the alignment of their magnetically susceptible elements with the earth's magnetic field during the process of cooling. Such remanent magnetism is also a property of rocks that have been heated in nature, especially volcanic or igneous rocks. Almost all the San Lorenzo monuments were carved from such rock—basalt—which is not native to the area but which was laboriously brought in from the Tuxtla Mountains, some 70 kilometers to the northwest (Fig. 2).

First of all, we had to determine whether or not magnetic surveying would aid the exploration of San Lorenzo, since most sites are, in fact, unsuitable for this technique. In February 1968, Rainey assessed conditions there and obtained samples of the monuments and of the fill in which they are principally buried. The induced and remanent magnetization of the monuments proved to be 2×10^{-4} and 4×10^{-4} emu, respectively, contrasted with a total magnetization of the fill of less than 3×10^{-5} emu. Thus, there was enough difference between the magnetism of the objects and the surrounding fill to make San Lorenzo an ideal site for the effective use of magnetic surveying. Further, there are no deeper-lying rock strata at the site to interfere with the observed anomalies; in fact, because there are no "natural" rocks, all anomalies would be significant. Finally, San Lorenzo is happily remote from any

Figure 3. Surveying the San Lorenzo site with the magnetometer.

Figure 4. This figure, over one meter high, represents the rain god (Monument 52) and is one of the finest of all Olmec sculptures. It was found as a result of the preliminary magnetometer survey.

recent man-made implements, vehicular traffic, other iron and steel interference, and electric power lines.

Magnetic surveying

The following month we brought a portable cesium magnetometer to San Lorenzo (Fig. 3). This instrument has a sensitivity of 0.1 gamma (10^{-6} oersted) and can be operated in either a "search" or "survey" mode (*7, 8*). As a search device, it was used to take occasional readings visually or audibly, noting more the location of the anomaly than its amplitude. This mode is useful for rapid reconnaissance, for obtaining an overview of site conditions, and for tracing long anomalies (such as a wall). We chose initially to traverse San Lorenzo on horseback, particularly in the high grass and some dense forest areas. The local saddles were made of wood, and there were no steel horseshoes to interfere with the instrument. Almost immediately, we located an anomaly and estimated the depth of what turned out on excavation to be one of the finest of all Olmec sculptures—a rain god with typical half-human, half-jaguar features (Fig. 4), lying at the predicted depth of $2^1/_2$ meters at the head of a buried drain system. Several more monuments were found in this manner, and archaeologists were as mystified as the local workmen at the uncanny ability of the magnetometer to "see" buried objects.

It was necessary, however, to conduct a survey systematically in order to obtain complete coverage of the area and to find objects that responded less noticeably to the sensor or that were more deeply buried. This required that we produce a magnetic map of the entire San Lorenzo

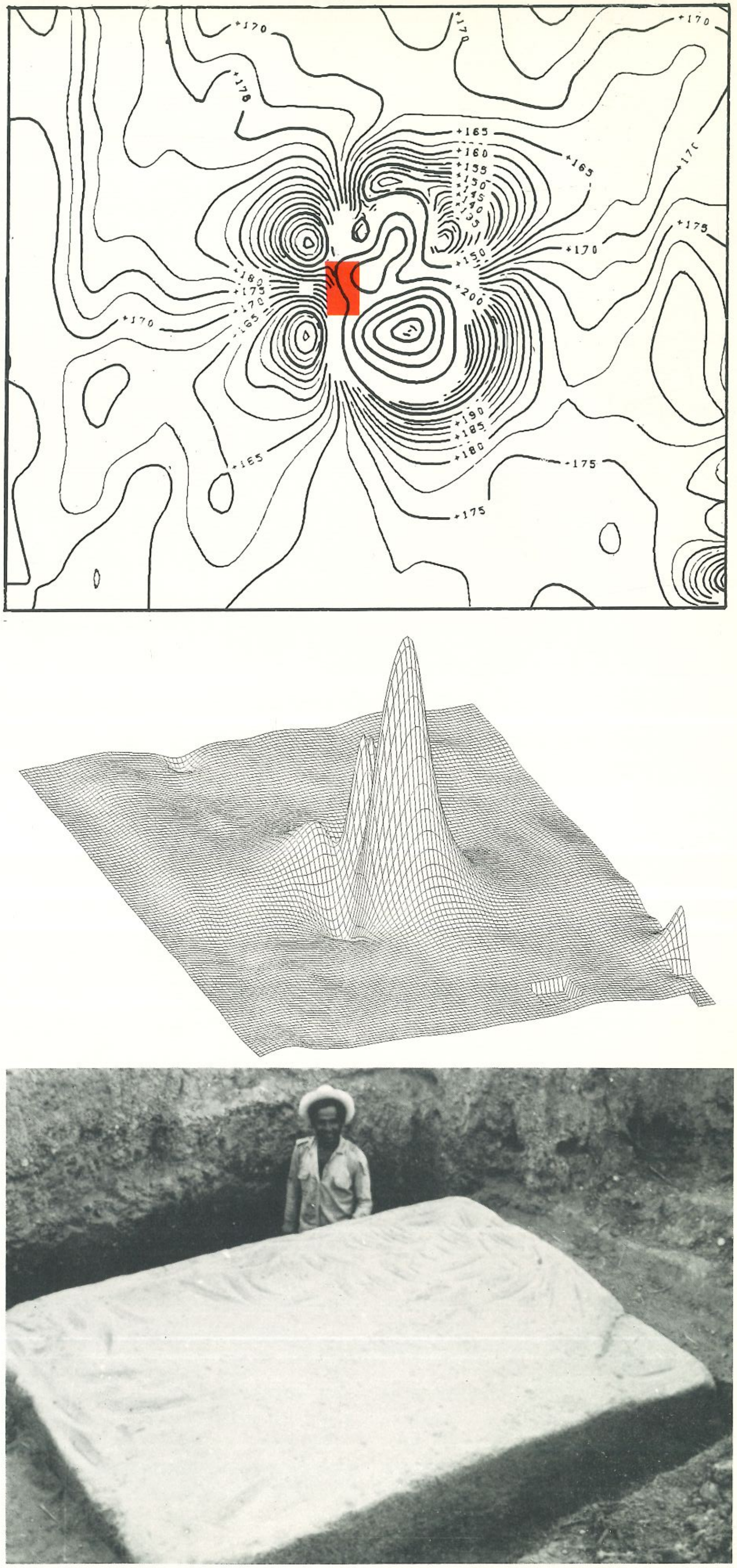


Figure 5. Total magnetic intensity contour map (*above*) and perspective view of contoured data (*center*) over a buried Olmec altar (Monument 51), shown (*below*) after excavation. The altar caused the prominent anomaly in the center, indicated by the colored block; other anomalies are caused by neighboring small monuments. The sharply defined square depression on the perspective view is the effect of missing data. The map represents an area approximately 50 meters on a side.

plateau, a program that was largely completed in the following field season by Elizabeth Ralph, of the Applied Science Center of Archaeology of the University Museum of the University of Pennsylvania. Mapping procedures using the instrument in the survey mode require that measurements be made on a regular grid whose dimensions are determined by the probable size and maximum depth of the anomalies of interest. We decided to seek Olmec monuments with a minimum size of one cubic meter, large enough to produce an anomaly detectable at a maximum distance of about 2 to 3 meters. This indicated a grid interval of 2 meters for the entire surface.

We divided up most of the accessible parts of San Lorenzo into approximately 31 major grids measuring 100 meters on a side. Ropes were marked off in 2-meter lengths and laid on opposite sides of each grid. A third rope marked similarly was laid between them along corresponding marks. A reading would be taken over each mark on the latter rope with the magnetometer held one-half meter above the ground. A total of 80,000 measurements were taken in this manner and transcribed to field notes or into a portable tape recorder held at some distance from the site of the measurements. Unfortunately, the steep terrain and dense forest precluded coverage of many areas of the plateau.

There are some inherent problems in a survey of this sort. One of the most serious is that the measurements show not only the magnetic variations of the underlying monuments and artifacts but also extraneous time variations of the magnetic field. These solar-induced time variations, called micropulsations or diurnal variations, make it difficult to sort spatial from time anomalies. To remove the major effect of the time variations, a constant value was added to or subtracted from each point on a given line to make the average value of that line equal to the average of the entire grid. Large line-to-line level offsets were thus eliminated, allowing for the preparation of a more presentable contour map.

Figure 6. A colossal Olmec head (Monument 61), buried at a depth of approximately 5 meters, was the most perfectly preserved large sculpture found at San Lorenzo.

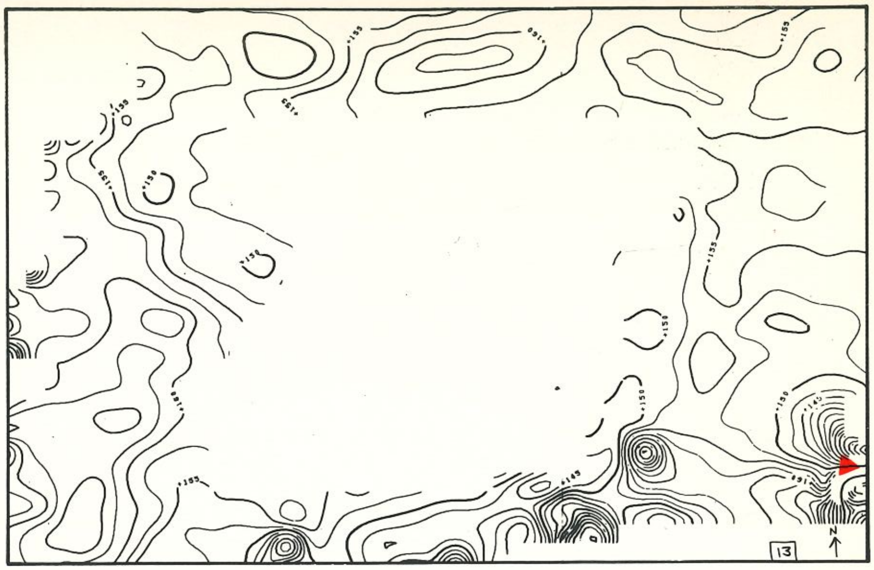


Figure 7. Contour map of magnetic intensity over Monument 61 (shown in Figure 6). The head was found under the anomalous area indicated by the colored marker in the lower right-hand corner of the map. The area at the center of the map was covered by a large artificial pond, where no measurements were made.

The survey results showed the effects of deposits of physically small but anomaly-producing artifacts, especially stone debris from ancient workshops. Also, because of the large grid interval, the effect of some moderately large monuments appeared principally on one grid point and only very subtly on several adjacent points, and the effect of very small monuments appeared on one grid point alone. In both cases there were doubts about the significance of that single data point. For all grids, therefore, we computed what the magnetic field would have been at an elevation one meter higher. In this way, more weight would be given to the subtle effect at neighboring points, thereby establishing greater confidence in the location and existence of an object of significant size, while the effect of the very shallow, small, and insignificant anomalies would be almost completely eliminated. This process, known in geophysical exploration as "upward continuation," is a mathematical technique based upon accurate knowledge of all the data on a plane surface.

Using points 2 meters apart does not produce a readily interpretable contour map, nor does it allow for much refinement in the location and character of the anomalies. We therefore computed, from the original 80,000 locations, an additional 400,000 points, using the bicubic spline technique, a method for low-order interpolation between the already established values. All the points thus computed were used to derive total magnetic field intensity contour maps of approximately 300,000 square meters over the San Lorenzo plateau, an enormous job accomplished by using a very efficient technique of electrostatic plotting. The maps were then interpreted for the precise location, depth, and estimated size of the anomalously magnetic features. Three-dimensional perspective views of the contoured data were also derived to portray vividly the complex magnetic field variations observed over the relatively simple geometric shapes of the monuments, as shown in Figure 5.

Survey results

The survey occupied three field seasons, during which archaeologists from Mexico's Instituto Nacional de Antropología e Historia and from Yale University conducted the digging to test whether there actually were monuments under the mapped magnetic anomalies. The largest and/or shallowest monuments, as determined above, were excavated first. Of course, some "dry holes" resulted from such features as burned soils or stone workshop debris (Fig. 9), but most efforts were crowned by success. Seventeen Olmec monuments were discovered that would otherwise have completely eluded even the shrewdest and most

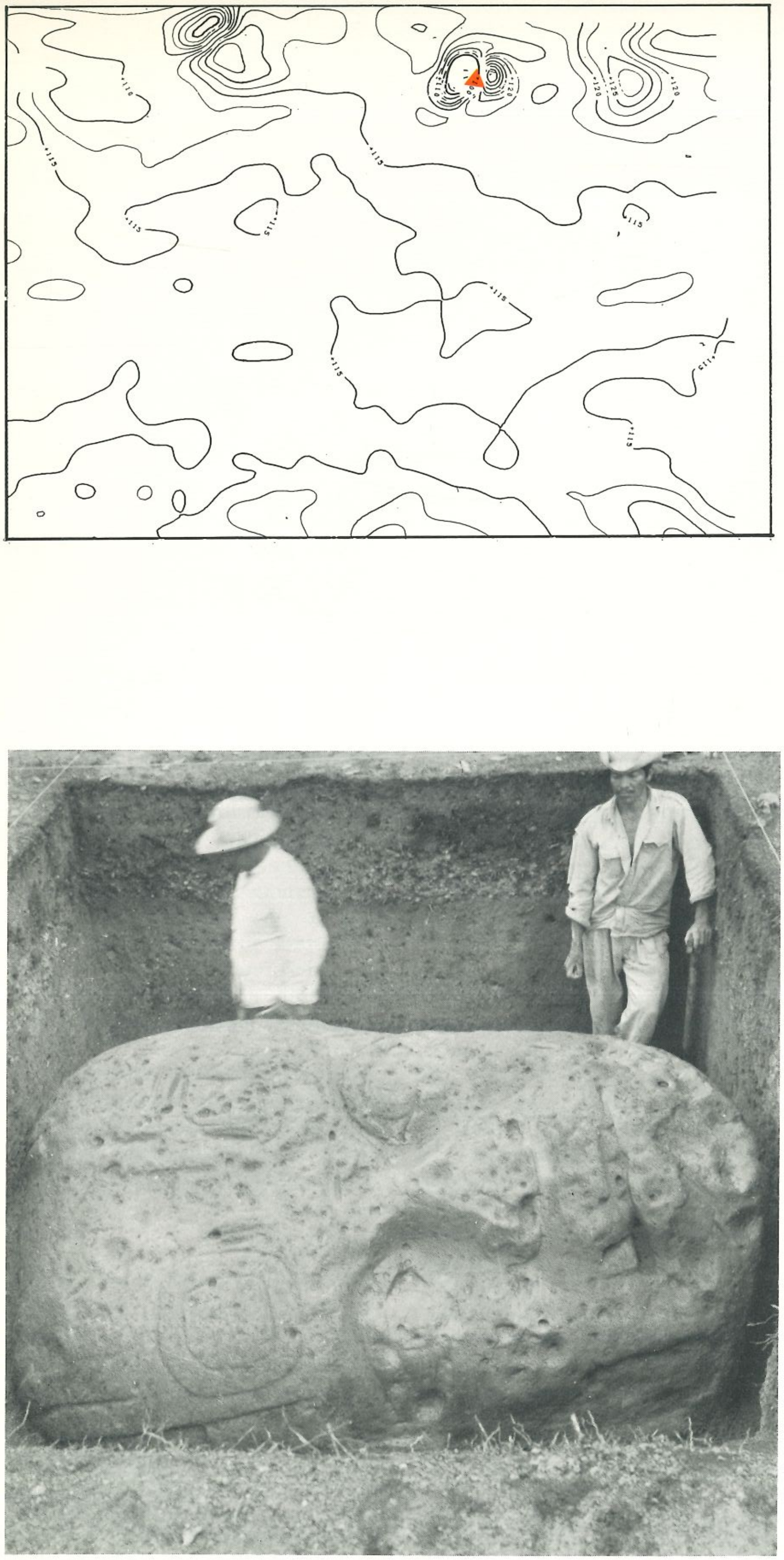


Figure 8. Contour map (*above*) of total magnetic intensity of a grid containing the colossal Olmec head (Monument 53) (*below*). The anomaly caused by the head is indicated by the colored marker at the top of the map.

patient archaeologist. The majority were not in the ridges (where the magnetic survey was incomplete) but on the central part of the San Lorenzo plateau, where we had not expected to find them. Among the most impressive were two new colossal heads: Monument 53, found lying face up and less than one meter deep, wears a unique helmet embellished with a pair of hands (Fig. 8); Monument 61, without doubt one of the finest masterpieces of pre-Columbian art, is a perfect, unmutilated sculpture which had been buried in a pit at a depth of 5 meters, presumably very early in the San Lorenzo phase (Figs. 6 and 7). It was missed by the iconoclasts in their mass act of destruction at the site.

Other stones included stelae, columns (one decorated with a bas-relief scene showing a man and a jaguar), fragments of oblong "altars," and a round "altar." One of the stelae bears a motif completely new to Olmec iconography, an extraordinary fish with the head of a jaguar, of entirely unknown significance. Monument 52, the important statue of the Olmec rain god, has already been mentioned.

The center of the mesa at San Lorenzo is occupied by a "pyramid" and a rectangular set of ridges extending in a north-south direction. The ridges exhibited a magnetic anomaly conformable to their topography, suggesting that their cores are composed of uniformly magnetic soil or other such material. The pyramid itself was entrenched through to its "floor" and the interior of the trench explored with the magnetometer for evidence of monuments. Clay materials, magnetic rock fragments, and uniformly magnetic stratified horizons were noted, but no monuments were detected or found.

After the San Lorenzo magnetic survey, the magnetometer was tried out on a similar pyramid at the great Olmec site of La Venta by Morrison et al. (*9*), of the University of California. One anomalous area was noted not far below the summit of the structure.

The magnetometer is thus a reliable and, so far, unique instrument for the prospecting of Olmec sites. It can save immeasurable time and expense in guiding excavations for the relatively "obvious" anomalies detected at such ideal sites as San Lorenzo. The magnetometer may also find use in the search for buried features producing "negative" anomalies, that is, features in the ground that have zero magnetization in contrast to their surroundings. Such features might be the hidden openings of underground tombs, such as those detected with the use of a magnetometer by Linington (*10*) in Italy. Tombs and buried entries are relatively common in the New World from western Mexico to Colombia.

It should be emphasized, however, that most sites are not suitable until proven otherwise through some knowledge of the magnetic properties of the archaeological features and the surrounding materials. Furthermore, someone experienced in magnetic surveying should be present, because the procedures of measurement and the interpretation of the results are still too complex for an archaeologist untrained in these techniques to carry out by himself. Under the right conditions, however, magnetic exploration should be a standard procedure at archaeological sites around the world.

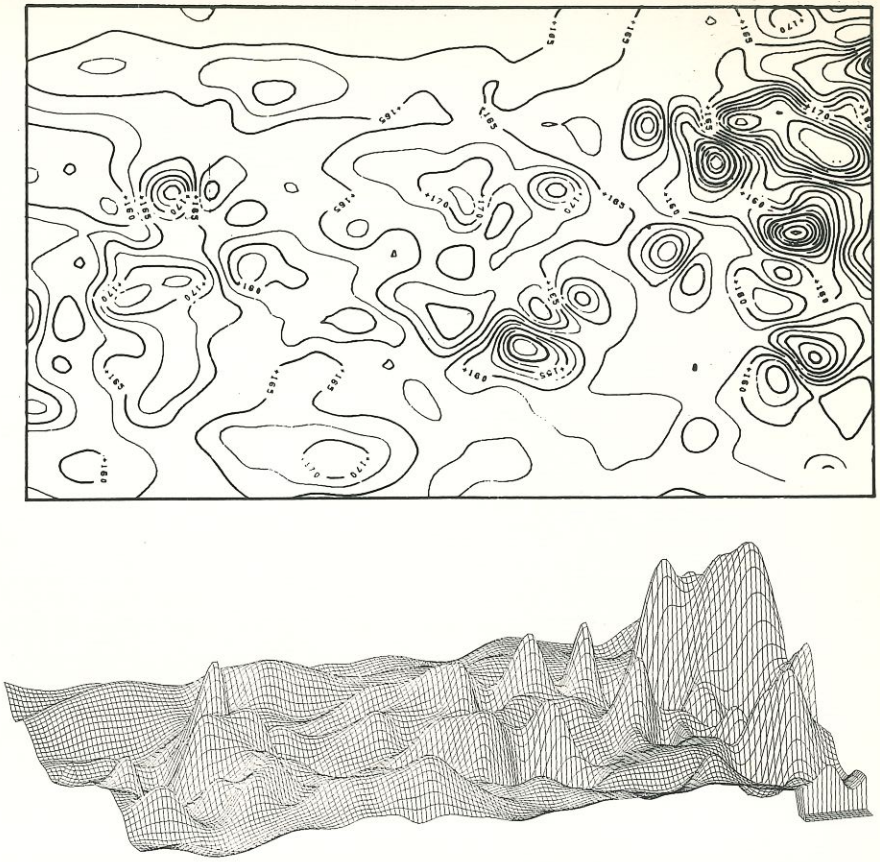


Figure 9. Total magnetic intensity contour map (*above*) and perspective view of contoured data (*below*) over an area described as a "workshop" and underlain by numerous small rock fragments possibly derived from monuments.

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FIGURE CAPTIONS

Fig. 1.	MASCA cesium magnetometer in use at San Lorenzo.
Fig. 2.	Varian Associates audio cesium magnetometer in use at San Lorenzo.
Figs. 3. & 4.	
Fig. 3.	Map of locations of magnetometer surveys overlain on
Fig. 4.	Map of San Lorenzo site made by G.R. Krotser, 1967 edition.
Notes:	Outlines and numbers of magnetometer grids are shown. Hatched regions are areas which were covered with the audio cesium magnetometer without laying out grids. The two maps were related by the benchmarks as designated by M, N, X symbols.
Fig. 5.	Magnetometer Grid #22.
Fig. 6.	Magnetometer Grid #19.
Fig. 7.	Magnetometer Grid #5.
Fig. 8.	Olmec head, Excavation 2-69, Grid No. 9.
Fig. 9.	Magnetometer Grid #9.
Fig. 10.	Magnetometer Grid #13.
Fig. 11.	Magnetometer Grid #14.
Fig. 12.	Magnetometer Grid #17.
Fig. 13.	Column, Excavation 6-69, Grid #17.

San Lorenzo Survey File Dr. Rainey

Ralph RSCA file

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Remote Sensing and
Interpretation

Magnetic Survey and Excavation Results
San Lorenzo Tenochtitlan
February-March, 1970
Marvin Harris/Sheldon Breiner

The San Lorenzo Survey of 1970 started 19 February. On Friday, 20 February, we went out looking for some of the anomalies that we knew were there from the results of the preceding two years.

1. The first one we found was on the south central ridge and it turned out to be somewhat insignificant. The location was at the isthmus; the anomaly turned out to be due to a stone about 6 inches across which was a metati stone, volcanic but with more magnetic effects than most of the other stones from which the monuments were made. It gave us large readings but it was very small itself, a depth of one-half meter.

2. A few minutes later we ran across another one that was further south on the same ridge, south of the isthmus and which was also a metati stone, also about 6 inches across.

3. Then we searched the area more thoroughly and at a point 20 meters northeast of monument 18, we got another reading - much broader - indicating it was deeper and a weaker reading. Although after we dug it, we found that it was a bench approximately 1 meter long and about on-half meter high, with legs, and made in an "L" shape. No markings of any kind appeared on the bench. It was on the edge of the flat, a little south-southeast of the isthmus, on the south central ridge.

4. The next monument that gave large readings was what we call monument 60 located approximately 80 meters southeast of the big altar discovered in 1968. This monument, however, turned out to be a small altar or at least that is what we called it. It was a large rock about 1-1/3 meters high, probably 1 meter in diameter, and buried 3.8 meters to its bottom. It was a square, large rock that had been rounded at the corners. No carvings were obvious, but there was a small notch or square-cut with 90° angles cut in one side of the rounded top.

5. The most significant find was the next monument we found, number 61, another large head, with an estimated weight of approximately 10 tons or more. It was at a depth of 4 meters and was found lying on its left side with the front of the face pointing southwest. The head was much more beautiful than the other heads, primarily because it was not very weathered. It was not defaced with marks like the other heads were, either. It also looked like more effort went into the carving of such features as the lips, the nose, and all features of the face were more pronounced. It appeared to be a larger head, I think, than monument 17 located near the isthmus. It was located approximately 30 meters southeast of the lagoon where the horses watered, that is, immediately east of the drains and the rain god found in 1968.

6. In the lagoon to the northwest of the head we began digging over readings which indicated a deep anomaly. However, we ceased the digging because of the water problem in the lagoon at very shallow depths.

7. Another monument that we found was a large disk, monument 64, almost directly south of the large head at a distance of perhaps 150 meters. It was a disk approximately 2 meters in diameter and 1/3 meter thick with a fairly flat surface. It had several major cracks through the entire disk. The markings consisted of two straight parallel lines, like cords, symmetric about a diameter which enclosed about half the area of the circle. Around one circumference at one end of the cord-enclosed area, there were several depressions somewhat equally spaced which could either be a design or defacing marks. At the other circumference of this cord-enclosed area were zig-zag lines which appeared to be some sort of design. The disk was buried approximately 1/3 meter deep to the top of its surface on the eastern slope of the southwest ridge down the side of the ridge approximately 20 meters.

8. Another monument which we found but which did not appear to be very significant, we called monument number 62. It was next to the big head directly to the southeast and was another stone that appeared to have been worked by man. It was flat on the bottom, slightly rounded, but we did not dig the stone clear to see what it actually was. We could see no carving, it was fairly small, with the edge of the stone perhaps one meter from the edge of the big head but buried at a high level such that the bottom of the stone was approximately the same elevation as the top of the head.

9. On the south central ridge we found another stone, monument 63, almost round and more or less egg-shaped, approximately 1-1/3 meters in its longest dimension. It was in grid number 27 in the western part of the south central ridge, a little north of the central part of the ridge and on the west side.

10. In grid number 14, there appeared to be rocks of many types with numerous magnetic anomalies as they appear on the grid number 14. It was as if the inhabitants used that area for dumping their chips and their rocks that they used for cutting other monuments or remnants of other monuments. This littered area includes all of northern grid 14, the southwest portion of grid 8, and the northwest corner of grid 10, all of which is heavily covered with anomalies. Digging out some of these which were near the surface turned out to be rocks which ranged between 10 and 50 centimeters across with no definite shapes, as if they were just broken fragments. I found 25 different variations of the rocks consisting mostly of volcanics, quartzite and perhaps a few igneous rocks. Approximately half of them were magnetic which we checked by moving the samples near the magnetometer. Most of the magnetic rocks were very strongly magnetic, the same as the metati stone. We took samples from all of the monuments and made magnetic checks on these rocks to note that there was quite a difference between the magnetic properties of the different monuments.

11. I found another anomaly on Group D ridge on the west end of the south edge of the ridge. This anomaly might be worth digging - perhaps 1 meter deep and 1 meter across in size.

12. We went to the end of the southeastern ridge and walked back. There seemed to be a lot of metal trash on the trail, pieces of wire, etc., but I did observe a large anomaly in about the center of that area where the ridge is very narrow, east of grid 28 and near where the isthmus appears across the arroyo.

The head that was discovered last year, monument 53 at the north end of grid 9, was a head that was very badly defaced and full of holes that was found less than 1 meter from the surface. Also last year, a hole was dug in the northwest ridge to find a large monument which turned out to be a large rock with no carvings.

I have photographs of all the monuments uncovered this year and have noted their locations approximately on one of the published topographic maps of the area. Getting around and getting permission to explore in many of the areas on the mesa is very difficult because the land has been sub-divided and given to the villagers. Many of them have refused to allow archaeologists on the property, others have planted corn, in other areas the jungle is very thick and new fences appear everywhere. The south central ridge is planted in corn, the southwest ridge is still jungle.

The instruments required repair on many occasions with only one sensor surviving in operable condition after parts from the other sensor were utilized. The only way the remaining cesium magnetometer could operate was by removing the heater card from the sensor electronics. The ambient temperature and the lamp temperature was sufficient to keep it operating. The audio reading magnetometer was the only model utilized in this year's work and proved very useful.

A Dr. Winnie attempted to reach me by telephone from Chapala, Jalisco. He wanted to know if I could come to Guadalajara for some work, however, he did not make contact with me to arrange for such a test. I returned 16 March.

Report by Marvin Harris. Written by S. Brome
March 27

cc: Dr. Froelich Rainey
Dr. Michael Coe

Fco. Beverido Pereau.
Avila Camacho, # 183.
Jalapa, Ver., México-

Abril 29 de 1969.

Miss Elizabeth K. Ralph.
Philadelphia, Penn.

Muy estimada amiga:

Recibí su amable carta del día 15 y también la copia de su artículo con las fotografías que ya deseo ver publicado y que seguramente causará gran interés entre los investigadores.

Con ésta le envío unas fotos de los últimos hallazgos, pues pienso que le interesarán, en ellas anoto algunos datos necesarios, y si usted desea publicarlas, yo no tendré inconveniente alguno.

Quisiera pedirle que envíe Ud. una carta al Dr. Ignacio Bernal, mencionando mi cooperación en el campo, será posible? Parece que nuestro buen amigo Roberto (jeep) no ha dado buenos informes de mi trabajo.

Ahora estoy en Jalapa, en mi cubículo del Instituto, con una fresca temperatura muy agradable, alguna lluvia por las tardes, pero sobre todo sin garrapatas y sin moscos. Con la familia, los viejos amigos y una buena copa para platicar sobre las aventuras pasadas, ya me siento mejor.

Que se encuentre bién, y no deje de informarme sobre sus próximas investigaciones.

Le recuerda con estimación su servidor y amigo

F Beverido

Martha -
Miss Bruckner has photo
of head